Farm level financial implications of foot-and-mouth disease control in extensive beef production systems

by

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Declaration

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Summary

The livestock sector, to which cattle contribute greatly, is a key component of agricultural production in South Africa. Beef production and consumption has increased over 30% in the last 10 years, a significant increase in volume and in value. Livestock farming is the only viable agricultural activity in large parts of the country. Approximately 80% of South African's agricultural land is only suitable for extensive grazing. Production challenges arise as a result of numerous factors such as climate change, government policy and animal disease. Foot-and-mouth disease (FMD) is one such challenge facing the industry.

FMD is a clinically acute, vesicular disease affecting cloven-hoofed animals which include domestic ruminants, swine as well as more than 70 species of wildlife. The Organisation for Animal Health (OIE) lists it as disease type A; a disease with the potential for rapid and far reaching spread within a country and between counties, causing severe economic impact. FMD is endemic to Southern Africa and so its impact is often felt; reservoirs of the disease exist in wildlife populations throughout the region.

The impact of FMD can be seen as direct losses or indirect losses. Direct losses refer to reduced production and structural changes in the herd in the event of an outbreak on one's farm. The indirect losses refer to the cost of disease control and limited market access as a result of control policies. The indirect loss on commercial producers in extensive production systems is the focus of this study. This study attempts to evaluate the financial impact of FMD control policies, put in place in the event of an outbreak to control and stop the spread of the disease. This was done by developing two whole-farm multi-period budgets for a typical extensive commercial beef cattle farm using two types of production systems. A fixed breeding season system and a year-round breeding season production system were used, during a production cycle where an outbreak of FMD occurred and control policies were implemented. Scenarios were run in order to simulate the disease outbreak occurring at different times during the production cycle as well as larger magnitudes of outbreaks.

The results show that FMD control policies can have an adverse impact on both production systems which were investigated. The year-round breeding season was financially less severely impacted than the fixed breeding season. When the outbreak occurs has a noticeable impact on both production systems and the resulting financial impact thereof.

Opsomming

Die lewendehawesektor, waartoe beesboerdery grootliks bydra, is ŉ sleutelkomponent van landbouproduksie in Suid-Afrika. Beesvleis produksie en verbruik het met meer as 30% toegeneem oor die laaste 10 jaar, ŉ aansienlike toename in volume en waarde. Lewende hawe boerdery is die enigste lewensvatbare landbou-aktiwiteit in groot dele van die land. Ongeveer 80% van Suid-Afrika se grond is slegs geskik as ekstensiewe weiding. Produksie uitdagings kom voor weens verskeie faktore soos klimaatsverandering, owerheid beleid, en dieresiektes. Bek-en-klouseer is een so ŉ uitdaging wat die industrie in die gesig staar.

Bek-en-klouseer is ŉ kliniese akute, vesikulêr siekte wat hoef-diere affekteer wat insluit makgemaakte viermaagdiere, varke en meer as 70 spesies wild. Die organisasie vir dieregesondheid lys dit as ŉ Tipe A siekte: ŉ siekte met die potensiaal vir snel- en wye verspreiding binne ŉ land of tussen lande met ernstige ekonomiese impak. Bek-en-klouseer is endemies tot Suid-Afrika en kom dikwels voor, poele van die siekte kom voor in wild populasies dwarsoor die streek.

Die impak van bek-en-klouseer kan direkte- of indirekte verliese wees. Direkte verliese verwys na produksie en strukturele veranderings in die kudde tydens ŉ uitbraak op die plaas. Indirekte verliese verwys na die koste van siekte bestuur en die beperking op marktoegang as gevolg van beheer maatreëls. Die indirekte verlies vir kommersiële produsente in ekstensiewe omstandighede is die fokus van hierdie studie. Die studie poog om die finansiële impak van bek-en-klouseer beheermaatreëls te evalueer in die geval van ŉ uitbraak ten einde die verspreiding van die siekte te beperk. Dis is gedoen deur die ontwikkeling van twee geheelplaas multi-periode modelle vir ŉ tipiese ekstensiewe kommersiële beesplaas vir twee verskillende produksiestelsels. ŉ Vaste teelseisoen en ŉ heeljaar teelstelsel is gebruik gedurende die uitbraak van bek-en-klouseer waartydens beheermaatreëls sou intree. Scenario's is gebruik om die siekte uitbraak te simuleer indien dit tydens verskillende periodes sou voorkom gedurende die produksie-siklus, asook langer periodes van inperking.

Die resultate wys dat bek-en-klouseer beheermaatreëls ŉ negatiewe impak kan hê op beide produksie stelsels wat ondersoek is. Die velaar teel-stelsel word egter finansieel minder beïnvloed as die vaste teel seisoen. Die tydsperiode waar ŉ uitbraak sou voorkom sal dus ŉ belangrike impak effek uitoefen op beide die stelsels.

This thesis is dedicated to my father Alwyn Smit and my grandfather Ted Harvey. Men whose passion for agriculture and cattle knows no bound. The salt of the earth.

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List of abbreviations

FMD	Foot-and-mouth disease
FMDV	Foot-and-mouth disease virus
GDP	Gross domestic product
OIE	World Organisation of Animal Health
SAT	Southern African Territories
SADC	Southern African Development Community
HS	Harmonised system
IRR	Internal rate of return
NPV	Net present value
SAM	Successive approximation models
RPO	Red Meat Producers Organisation

Chapter 1: Introduction

1.1 Background and motivation

For centuries livestock has been a cornerstone of society, providing food, transport, status, raw material and wealth. To a large extent this still holds true in modern day society where the livestock sector plays an important role in the South African economy as well as society. From a resource perspective most of South Africa's farmland is only suitable for extensive livestock production. These areas are characterised by relatively arid climates and drought conditions are common. Over time the South African beef and mutton industry has developed a sophisticated transport system to serve the network between farms, auctions, feedlots, abattoirs and breeders. This, amongst other things, creates a real risk for the spreading of disease.

Animal diseases are one of the greatest risks to the industry and to society. Foot-and-mouth disease (FMD) is one such disease. Whilst it does not have a direct impact on human health it causes significant damage and disruption to local economies at all levels as well as international trade (Bender, Hueston and Osterholm, 2006). FMD is a disease which affects cloven-hooved animals, both wild and domesticated, such as cattle, sheep, goats, pigs and game animals. Some areas of the world are free from FMD; however, it is endemic in parts of South America, Asia and Africa. Countries which are free from FMD include New Zealand, Japan, North America as well as most European countries. The danger of the disease lies not only in the number of species which it affects, domesticated and wild alike, but also in its highly contagious nature and thus the ease with which it spreads. Transmission of the disease can occur through direct as well as indirect contact with infected animals. Aerosol, artificial insemination, contaminated vehicles, fomites and animal products are all documented means in which FMD has been spread (Alexandersen, Zhang, *et al.*, 2003)

The impact of FMD on stakeholders is not really characterised by the level of mortality which occurs as this is relatively low, but rather by the large quantity of animals which are affected and the loss of market access as a result of an outbreak. The impact can be divided into two components, direct losses and indirect losses. Direct losses refer to reduced production and structural changes in herds. Indirect losses refer to the costs of disease control and the limited or absence of access to markets (Knight-Jones *et al.*, 2016). Socio-economic costs also play a role especially on rural households who rely heavily on livestock.

Market access depends on freedom from trade related diseases such as FMD. Therefore, it is important to obtain and maintain an FMD free status which will allow trade of animals as well as animal products such as meat and wool on a regional and international level. From a Southern African perspective, some countries have developed mechanism to separate domestic animals from wildlife where known reservoirs of the virus exist and especially within Cape Buffalo (*Syncerus caffer*) populations (Knight-Jones *et al.*, 2016). Most notable are manmade cordon fences and meat checkpoints. Additionally, strict biosecurity measures must be in place between different status zones, thus serving to contain the disease within these infected areas.

Economic development and growth in the agricultural sector rely on trade which makes obtaining a FMD free status and maintaining it critical. Gross value of agricultural production in South Africa is categorised by horticultural, field crops and animal products. In the 2017/2018 season the total gross value of agricultural production was estimated at R 281 370 million. Animal products contributed a significant 50.6%, cattle and calves slaughtered making the second largest contribution thereof at 13.5% (DAFF, 2018b). In the event of an outbreak, control policies are put in place to control and prevent the spread of the disease. These control policies impact not only the producers, which are directly impacted but also those who are not. Negative externalities are incurred as a result of control policies, such as limited market access, movement control, higher transactions costs and disruption of the price determination mechanism. The extent to which these externalities impacts producers is unknown, from a production perspective as well as from a financial perspective.

1.2 Problem statement and research question

FMD is regarded as one of the most important livestock diseases in the world, in part, due to its contagiousness. It is endemic to Southern Africa and so its impacts are often felt in the region (Dion, Van Schalkwyk & Lambin, 2011). The control thereof and the control strategies in the event of an outbreak are of paramount importance. It is common knowledge amongst stakeholders in the South African beef cattle industry, as well as the livestock industry, that in the event of an FMD outbreak serious nationwide market shocks and disruptions occur. This is in part due to the control strategies implemented nationally in order to control the spread of the disease. Whilst no argument can be made against the importance of controlling the disease and stopping the spread there of, the impact which control policies have on producers must be considered. A lack of knowledge exists in terms of the indirect impact, with reference to the control policies, that FMD has on the livestock industry and in this instance primarily on the beef cattle industry. Within the industry itself, the impact and effect thereof may potentially vary depending on the production system utilised.

The main research question is; what the financial impact of FMD control policies are on extensive commercial beef cattle producers in South Africa which make use of different production systems? Reference is made to an outbreak occurring within a production cycle and how the impacts affect producers making use of different production systems.

1.3 Research objectives

Section 1.2 highlights the need for research to be conducted on FMD control from a financial producer level perspective. The main aim of this study is to evaluate the structural and financial impact of the FMD control strategy on extensive commercial beef cattle farmers and how the impact thereof differs depending on the production system utilised by the producer. Exploratory research aims to provide estimates of the financial implications resulting from the implemented FMD control strategy in different production systems. The following objectives should provide insight into production level managerial decision making regarding future FMD outbreaks.

- Describe the farm level implications for extensive farmers in the event of an outbreak.
- Identify a typical farm for the central extensive farming area that can serve as a basis for financial comparison.
- Identify and represent the use of different production systems based on the same typical farming enterprise.
- Determine an estimate for the structural and financial implications of control policies implemented due to FMD.

1.4 Research methodology

This study aims to evaluate the impact of FMD control strategies on extensive commercial beef cattle producers and the change in impact that occurs due to different production systems available to producers. The research conducted focuses on commercial producers opposed to stud producers, as herd and farm structure differ significantly. For the aforementioned to be achieved a literature review relating to the multiple factors associated with FMD is constructed. These factors include animal health economics, regulation and disease policy as well as production systems. The model construction and financial evaluation thereof is facilitated by the abovementioned factors. FMD is a facet of farming that adds to the unique challenges of beef production. To assess the effect of FMD on a farm system requires the integration of the effect into the system's functions. For that reason, a research approach is required that can easily integrate disruptive events into the farm financial system to determine the effect. The systems approach is specifically designed for this purpose. Farm budget models are one such user-friendly technique within a systems approach.

Two whole-farm multi-period budget models are constructed based on one typical extensive commercial beef cattle enterprise. The data used to create the models was obtained from producers, agricultural business and governing bodies which are involved in the beef cattle industry. The one model mimics a fixed breeding season herd structure and the other a year-round breeding season herd structure. The models allow the study to differentiate the impacts experienced by producers which make use of different production systems. Through the use of a spreadsheet program, the whole-farm multi-period budget models are constructed which simulates on farm activities in terms of production and translates physical production into financial outputs. Revenue generated through the sale of livestock through marketing channels will be accounted for as well as the monthly variable and fixed costs typically incurred. The structure of the models is such that hypothetical situations related to the control policies which have production as well as financial impacts can be simulated. Thus, the budget models are used to put production into financial perspective and to evaluate that perspective, regardless of the unique physical characteristics.

1.5 Assumptions

For this study, a typical commercial beef cattle farm which makes use of extensive production practices was simulated as whole-farm multi-period budgets. The unit simulated is a "typical farm", this typical farm does not exist; however, it is rather a representative of a typical farm in the region which is being studied. In this study the region which is being studied is the Vryburg region in the North West province, a region which has a semi-arid climate and makes use of extensive grazing systems for livestock production. For the construction of a typical farm model, numerous assumptions are required, all of which were made as objectively as possible, this being done by consulting the relevant shareholders in the industry as well as by consulting the relevant literature available.

1.6 Research outline

In Chapter 2 an overview of FMD provides the reader with an understanding of the disease. The overview informs the reader about the disease, so that the importance of the control and the spreading thereof can be placed into context. Topics such as transmission and pathogenesis are discussed. Chapter 3 provides an overview of the relevant literature, including topics such as industry perspectives and animal health disease situations in South Africa. In Chapter 4, the development and structure of the models created is described, additionally any pertaining theory related to budgeting, model construction as well as typical farm theory is discussed. Simulations relating to the hypothetical disease control scenarios are described. Chapter 5 presents the results of the whole-farm multi-period budget models, for a fixed breeding season as well as a year-round breeding season. The results for the hypothetical simulations which were conducted on both models and so both production systems are presented. Chapter 6 concludes the study, in which a summary, a conclusion and recommendations are presented.

Chapter 2: An overview of foot-and-mouth disease

2.1 Introduction

The main aim of this research is to determine the farm level financial impact that FMD and the control thereof has on commercial cattle producers. The highly infectious nature of FMD makes it a key quarantine disease. The study also helps to better understand the consequences of an outbreak and of the control measures utilised to contain the spread of the disease. Chapter 2 provides an overview of FMD which contextualises knowledge about the spread and control of the disease. Topics such as description, serotypes, pathogenesis, clinical symptoms and transmission are discussed in this chapter. It is important to note the transmission and spread of the disease, both within domestic livestock as well as free roaming wildlife species. These are important factors to account for when implementing a control strategy.

2.2 Foot-and-mouth disease

Foot-and-mouth disease (FMD) is a clinically acute, vesicular disease effecting cloven-hoofed animals which includes domestic ruminants, swine as well as more than 70 species of wildlife (Alexandersen, Zhang, *et al.*, 2003). The foot-and-mouth disease virus (FMDV) is classified within the *Aphthovirus* genus and as member of the *Picornaviridae* family (Belsham, 1993). FMD is classified by the World Organization for Animal Health (OIE) as an OIE List A disease. By definition this means it is a disease which has the potential for rapid and far reaching spread within a country and between countries, causing severe economic impact. The clinical diagnosis of FMD is not straightforward for several reasons. In some species which can be infected the clinical signs can be mild, for example in sheep and goats (Callens *et al.*, 1998). Furthermore, individual strains of the virus may be of low virulence for certain species. Several other vesicular diseases such as swine vesicular disease and vesicular stomatitis cannot be distinguished from FMD solely on clinical finding. For an absolute diagnosis to be made, laboratory testing and investigation is required.

FMDV consists of distinct serotypes that have been defined and which have indistinguishable clinical effects. The types are O, A, C, Southern African Territories (SAT) 1, SAT 2, SAT 3 and Asia 1 (Alexandersen, Zhang, *et al.*, 2003). Within a serotype a wide range of strains can potentially occur. These tend to be divergent enough to reduce the effectiveness of vaccines. Recovery from an infection or vaccination of a serotype will not necessarily protect animals against future infections from another strain. A further complication can arise where, after the acute stage of infection of FMDV a prolonged, symptomless infection can occur in ruminants, these animals are referred to as carrier animals (Stenfeldt *et al.*, 2016). The potential for carrier animals and the transmission of the disease from these animals has an impact on the control and eradication strategy which is utilised in managing the disease.

A stamping out policy is one such method of managing the disease, where all susceptible animals which are infected and those that are apparently normal are slaughtered on the property where the outbreak occurred. This method is utilised on the premise that total slaughter is required in order to eradicate the virus. Where this policy is not adopted the perception is that some of the animals which are allowed to survive could potentially be carriers and pose a continuous risk of a reoccurrence of the disease. This perceived risk from the carriers has a notable impact on the precautions taken to manage the international movement of livestock. The measures which are in place vary from nation to nation based on whether the disease is endemic or sporadic but can include complete embargo, quarantine and testing.

2.3 Southern African Territories (SAT) serotypes

The Cape Buffalo (*Syncerus caffer*) is one of the most prominent hosts on which overt disease symptoms are seldom observed. These carriers have been shown to be persistently infected, occasionally with multiple serotypes and for extended periods of time. A duration of 5 years has been recorded in a carrier (Condy *et al.*, 1985). The SAT serotypes have typically been confined to sub-Saharan Africa; however, several outbreaks of SAT 1 have been recorded in the Middle East.

- FMD virus type SAT 1, has been subdivided into three topotypes which are found in different areas. Topotype 1 first occurred in southeastern Zimbabwe and South Africa, including the Kruger National Park. Topotype 2 or WZ occurs in western Zimbabwe, Botswana and Namibia. Topotype 3 or NWZ is found in northwestern Zimbabwe, Malawi and Zambia.
- FMD virus type SAT 2. Studies conducted by Vosloo, Thomson & Knowles, (1992); Bastos et al., (2000) demonstrated that the SAT 2 virus from Southern Africa falls into two topotypes. One of which occurred in Zimbabwe and the other throughout Southern Africa, extending into the Middle East. Unlike SAT1 and 3 this virus type does not seem to fall into the same geographically based grouping.
- FMD virus type SAT 3. Three topotypes of this strand have been recorded, I-SEZ south-eastern Zimbabwe and South Africa, II-WZ western Zimbabwe and Botswana and III-NWZ north-western Zimbabwe and Malawi. Similar geographic distribution appears to occur between SAT 1 and 3 (Knowles and Samuel, 2003).

2.4 Pathogenesis

Infection of FMDV can be a result of direct or indirect contact with either infected animals or an infected environment. When an infected and susceptible animal are in proximity of one another the most common mode of transmission is through aerial transfer, droplets and droplet nuclei. Long range airborne transmission is uncommon but possible, requiring a combination of factors such as animal species, favourable topographic conditions, quantity and location of infected and uninfected animals. Studies conducted by (Alexandersen, Zhang, *et al.*, 2003) show that direct contact is the most common mechanism for the spreading of FMD.

Direct contact comes in the form of mechanical transfer from an infected animal through a cut, abrasion or mucosae of an uninfected animal. Infection by aerosol (droplet-nuclei) into the respiratory tract of susceptible animals, also transfer FMD. The epidermis when intact provides a measure of protection from infection; however, if the epidermis is damaged it lends itself to infection. Activities such as blood sampling, rounding up and inoculating, to name a few, increase the risk of indirect spread of the virus due to a damaged epidermis.

Airborne transmission can occur under certain climatic conditions. It is possible that short distance droplets and nuclei transmission can be extended to long range airborne transmission; however, it depends on a host of factors. Pigs are significant in this regard as they are a highly domesticated species and often produced in intensive farming systems. Pigs liberate the largest quantity of the airborne virus and are found in high density areas (Alexandersen, Quan, *et al.*, 2003). Ruminants are found to release less virus particles in their breath as opposed to pigs, ruminants are however more susceptible to infection from the respiratory route. To a lesser extent aerosols can also be created through the splashing of milk or urine of infected animals.

The incubation period is defined as the period between exposure to an infected dose until the first appearance of clinical symptoms. For FMD incubation is highly dependent on several factors. Incubation periods of as short as 24 hours and as long as 14 days have been recorded. The duration of the incubation period depends on factors including, the strain of the virus, dose, method of transmission, species and animal husbandry practices. The factor which has the greatest impact has been shown by Alexandersen, Quan, et al., (2003) to be the dose the animal receives; larger doses of infected material results in shorter incubation periods.

All secretions and excretions by infected animals become infectious during the course of the disease. Fluids such as saliva, semen, nasal fluid and milk are contaminated whilst urine and excrement, to a far lesser extent. The excretion of the virus in milk and semen occurs before any clinical symptoms are present in the animal (Alexandersen, Quan, *et al.*, 2003) which makes the physical movement of these and similar fluids of special concern before any clinical symptoms are observed. Examples of mechanical spread include the use of animal transport vehicles which have not been cleaned and the transport of contaminated milk in bulk tankers. Excretions have the potential to survive in the environment for extended periods of time, ranging from days to weeks to months. The main factors of survival are ambient conditions such as temperature, pH, moisture, relative humidity as well as the material which is infected like fodder, clothing or equipment. Low temperature a neutral pH and moist conditions seem to favour the survival of the virus (Alexandersen, Zhang, *et al.*, 2003).

2.5 Clinical symptoms and development of lesions

FMD is characterised by an acute febrile reaction and the development of vesicles in and around the mouth as well as on the feet. The resultant pain from these lesions causes lameness, a tucked-up stance and a reluctance to walk or to stand. Lesions develop and subsequently become vesicles found primarily in and around the mouth and feet area. It can however, also be found on the muzzle, teats, vulva and mammary gland. Clinical symptoms in cattle are generally more easily observed compared to other species, including drooling of saliva and mouth legions which are severe. Lesions found in the mouth of large ruminants are most often seen on the tongue and dental pad; however, it can also be observed on the lips, gums and cheeks. Severe inflammation in the feet during the acute stage can result in the horn of the hoof separating or being shed, this is known as thimbling. This most often occurs in pigs but during severe bacterial infection it is also observed in cattle and sheep. Adult animals have a low mortality rate and a higher rate is found among younger animals. The reasons for the higher mortality in younger animals are attributed to myocarditis, defined as an inflation of the heart muscle.

In addition to lesions FMDV induces a severe proinflammatory reaction which results in fever, depression, reduced feed intake and inability to maintain body temperature. Some ruminants which are exposed to FMDV become carriers, irrespective of the fact that they are fully susceptible or have been protected by a vaccination or have recovered from infection. The maximum duration of the carrier state is as follows: cattle three and a half years, sheep nine months, goats four months and African buffalo five years (Alexandersen, Zhang, *et al.*, 2003).

2.6 Conclusion

The supplementary literature in this chapter on FMD provides context on the disease and why the control thereof is essential. Elaborating on the animal health affects which it has on livestock in the event of an outbreak and the transmission therefor. The literature reviewed in this chapter will assist in the development of whole-farm multi-period period budgets, further discussed in

Chapter 4. The literature discussed forms a basis from which further literature studies can be conducted relating to industry and trade as can be seen in Chapter 3.

Chapter 3: Literature review: animal health economics

3.1 Introduction

Foot and mouth disease is regarded as one of the most important livestock diseases in the world (Dion, Van Schalkwyk & Lambin, 2011), largely due to its impact on trade and market access. Consequently, financial and economic losses are incurred on multiple levels throughout the industry, be they individual producers, regionally or nationally.

The literature discussed in this chapter aims to contextualise the cattle industry in South Africa as well as the animal disease situation. Industry perspective includes market access, contribution to the economy as well as the production systems utilised. The animal disease situation is reviewed in terms of the economic and financial impact as well as regulations concerning animal disease, with specific reference to FMD.

3.2 Agricultural contribution to the South African economy

Agriculture's contribution to the national economy is complex and multifaceted. However following world trends, it has been shown that agriculture's contribution to gross domestic product (GDP) has been steadily declining. South Africa's agricultural sectors' contribution in 1970 was roughly 7% to the GDP and in 2018 that relative contribution dropped below 3% as shown in Figure 3.2 and Figure 3.3 (DAFF, 2018a). The real contribution however is more complex and referred to as market linkages and incorporate factors such as earner of foreign exchange, provider of food, source of employment, source of capital as well as buyers of inputs from the manufacturing sector.

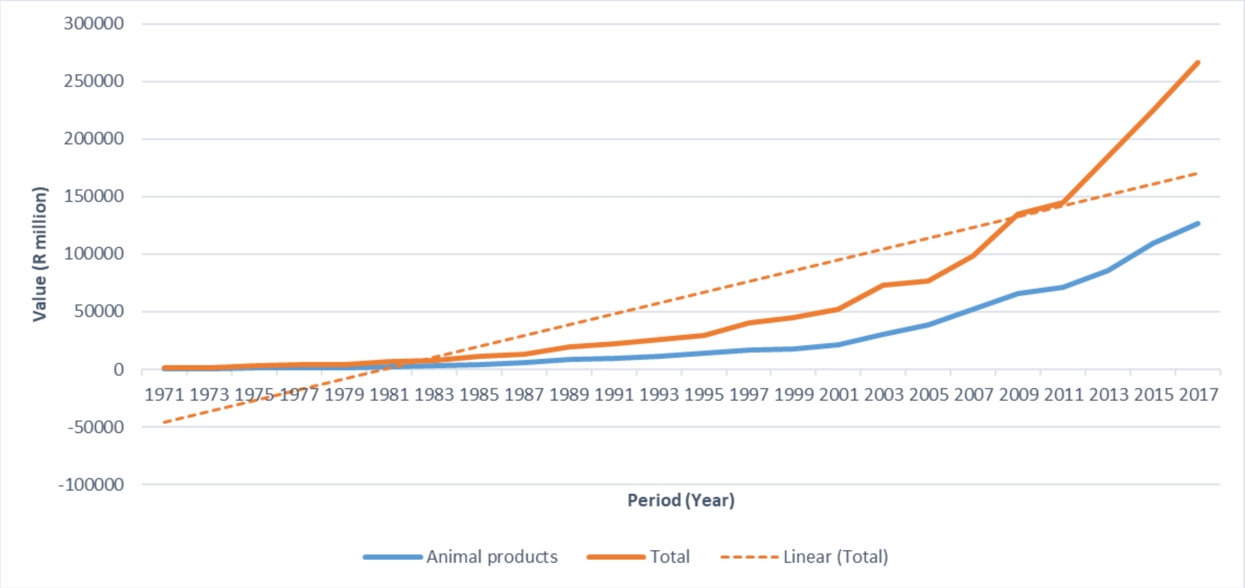

Figure 3.1: Annual gross domestic product for agricultural and animal products contribution

Source: DAFF (2020)

Additionally, it is important to note that although the relative contribution of agriculture to the national economy has decreased, the industry has grown substantially as can be seen in Figure 3.1 and Figure 3.2 bellow. All be it at a slower rate than other industries, for instance the mining industry. Animal products contribute to total agricultural gross domestic products, follows a similar upward growth curve, growing and adding value over time.

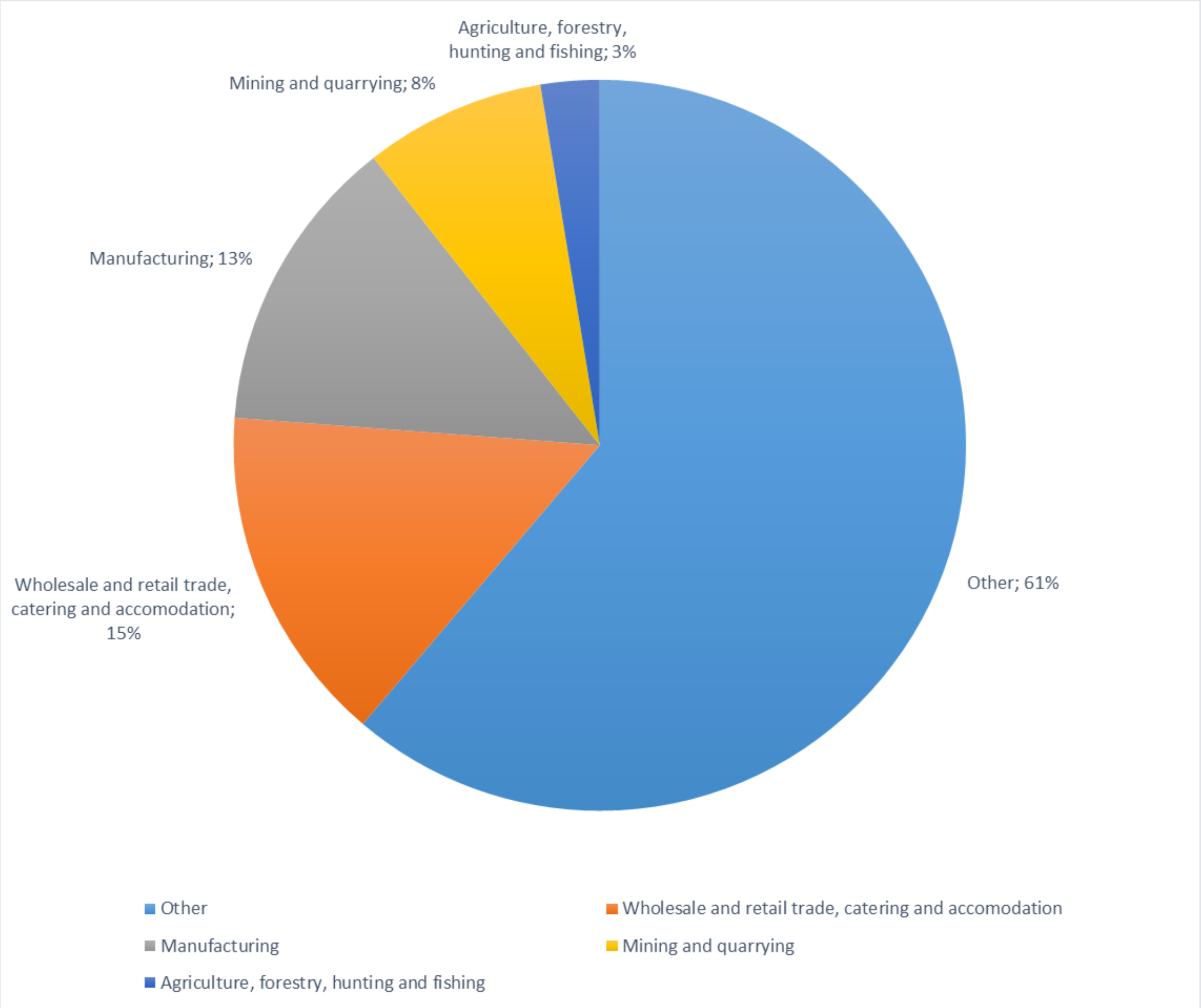

Figure 3.2: Percentage contribution to gross value added by industry for 2017

Source: DAFF (2020)

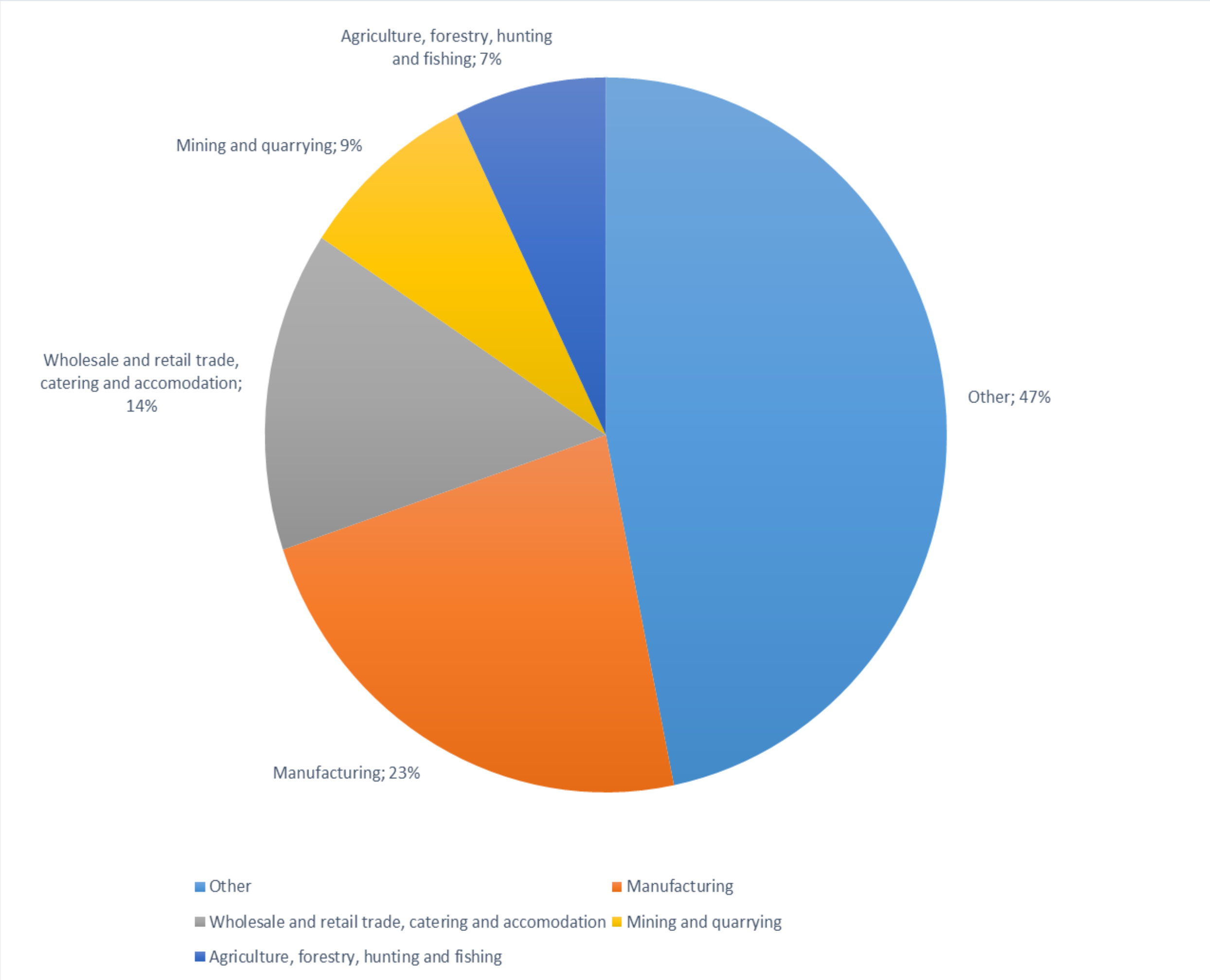

Figure 3.3: Percentage contribution to gross value added by industry in 1970

Source: DAFF (2020)

The impact agriculture has on the economy is not fairly represented by the 3% contribution to GDP as it does not operate in a closed system. Strong forward and backward linkages occur which interact with other industries to facilitate trade, commerce and employment. Agriculture, furthermore, is a labour intensive industry compared to other industries. The census of commercial agriculture report released in 2017, showed that 757 628 people are employed in this sector, farming of animals comprised 21.4% of the sector's employment and mixed farming of animals and crops contributed a further 24.5% of labour in the sector (Stats SA, 2017). South African agriculture maintains a positive trade balance which means it generates valuable foreign currency. South Africa is an importer of some primary foods, including wheat, in which the country is not self-sufficient. The positive trade balance is achieved by the net export of high value agricultural products which include fruit and wine. These products would benefit from a weakening of the exchange rate against for instance the Euro, Pound or Dollar.

The South African agricultural sector continues to play an important role in the economy regardless of its declining share of GDP. This is critical seeing as agriculture consumes large quantities of land and available water as production resources. Field crops, horticulture and livestock are the three main branches of agriculture nationally. The production areas needed for each individual crop and livestock depends on the natural resources of each geographic area. In large parts of South Africa, primarily due to arid conditions, livestock farming is the only viable agricultural activity. Approximately 80% of South African agricultural land is only suitable for extensive grazing (DAFF, 2018a).

Without exception the production of cattle for the slaughter market are produced in every province in South Africa. The quantity of cattle produced commercially through slaughter is not necessarily the number of cattle available in those areas but rather on the infrastructure such as feedlots and abattoirs in an area (DAFF, 2018a). The industry has a highly developed underlying transport system and infrastructure that facilitates the movement of cattle and calves within South Africa and often from other countries as well, for example Namibia and Botswana.

Local beef production fluctuates annually depending on a host of factors, but primarily its rainfall. Drought conditions have a long-lasting impact on the industry, extending beyond one production year. This is due to the nature of beef production and so the extended period needed to build up herd numbers of productive breeding stock. Following trends of the period 2007 until 2017 production has increased by 36% and consumption has increased 34%, subsequently the country is self-sufficient in terms of production (DAFF, 2018a).

The established livestock numbers in South Africa are shown in Figure 3.4. The Eastern Cape, Free State and KwaZulu-Natal contribute the highest percentage of cattle nationally with 25%, 19% and 17% respectively. These three provinces accounts for more than half the national herd. However, due to transport and infrastructure mentioned above South Africa herd and slaughter numbers per province are significantly different. Mpumalanga 21%, Free State 18% and Gauteng 16% are respectively the largest provincial producers of beef slaughtered in the country. The beef supply chain is becoming increasingly vertically integrated which stems from a greater number of commercial producers feeding their own cattle for slaughter. Additionally, many of the larger feedlots which purchase cattle for feeding, own their own abattoirs. Further integration in the value chain occurs as feedlots open retail stores and sell directly to the consumer market (DAFF, 2018a).

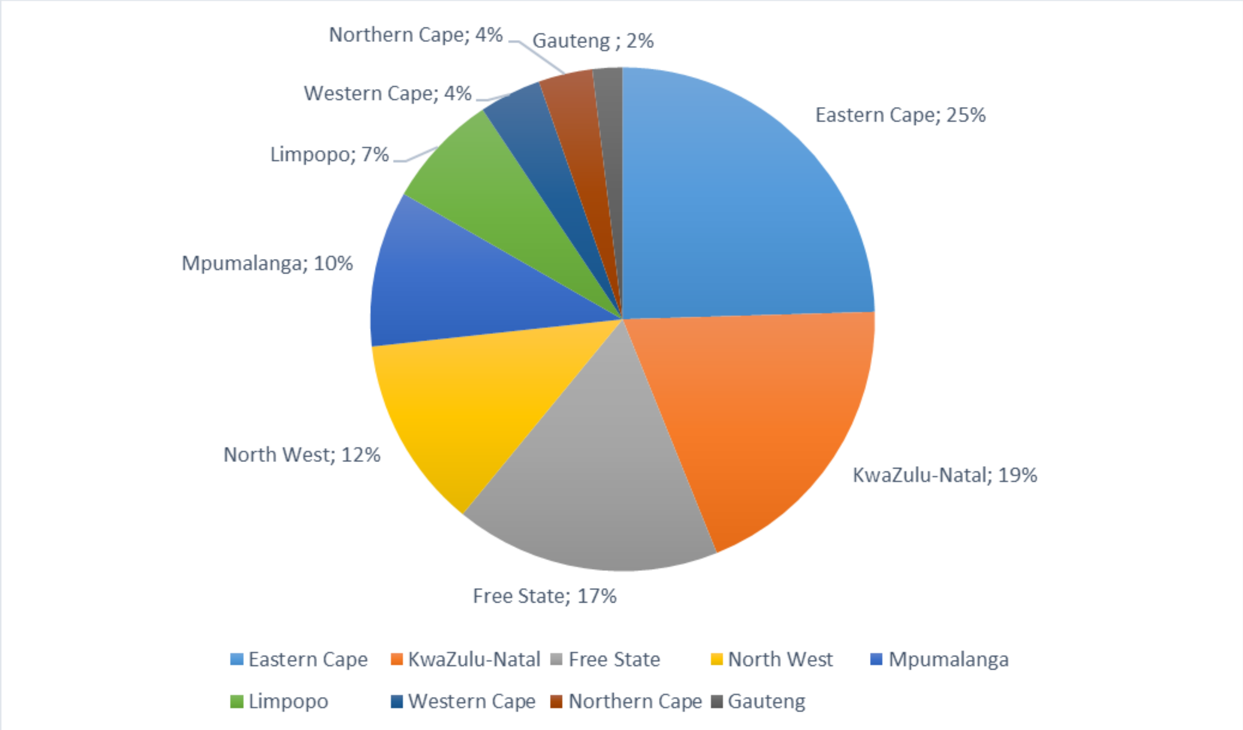

Figure 3.4: Estimated cattle numbers in South Africa per province November 2019

Source: DAFF (2020)

3.3 Market access

The red meat industry in South Africa has undergone many changes since the 1990s. It evolved from a highly regulated industry to one which is now totally deregulated. Of the regulations which were done away with was the distinction between controlled and uncontrolled areas, supply control via permits and quotas and setting of floor prices. Since the deregulation in 1997 the mechanism for price determination has become purely based on supply and demand factors. The local average consumption of beef per capita has increased significantly between 2007/08 to 2016/07 and can be attributed to the rising income level of the South African population (DAFF, 2018a).

Several marketing channels are available to producers in order to sell their livestock. The role players in the industry are the producers as well as speculators, livestock agents, feedlots and abattoirs. With reference to live animal sales opposed to meat products. Producers choose a production system which works best for them before marketing. In general, commercial farmers make use of two main types or productions systems. The weaner system where producers focus on producing weaner calves between 200kg to 260kg or six to eight months which are sold to be fattened and finished elsewhere, typically in feedlots. Then there is the oxen system where producers raise their own weaner calves until they are ready for the consumer market at roughly two years. These sales are primarily for the abattoir. The oxen system is typically found in more semi-arid regions which, due to their climatic conditions, are prone to droughts. A point of no return also occurs where the animals reach a weight or age where feedlots no longer wish to purchase those animals for typical market prices and so they must be carried until they are ready to be slaughtered or sold at reduced prices. A higher level of risk can thus be associated with the oxen production system. A combination of these systems can be utilised as well as commercial producers running their own feedlot system and marketing to the abattoir directly, avoiding the transaction costs which are associated with cattle agents and livestock sales.

Production relies on the relationship between various quantities of inputs and outputs. In agricultural production this is no different, various inputs such as land, labour and capital are utilised to produce animals which can be sold, be they in the form of weaner calves, oxen or cull animals. An overview of a beef cattle production system is illustrated in Figure 3.5. The main marketing channels are shown with specific focus on the production of weaner calves as well as the marketing options which are available to the producer.

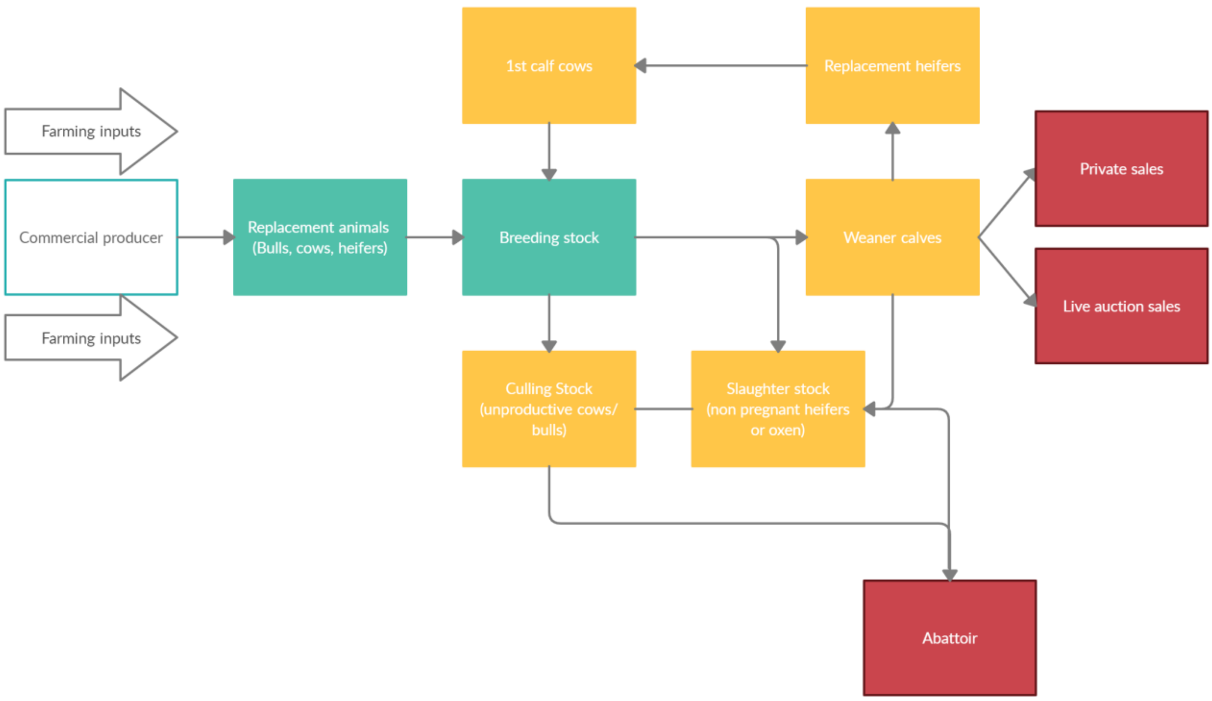

Figure 3.5: Beef cattle production system
Source: Adapted from Olivier (2004)

The marketing channels available from which revenue can be generated are auctions and abattoirs. Focusing on the weaner production system, producers can market their livestock through several channels using numerous role players. Private sales of weaner calves, directly from the farm to a buyer, such as a feedlot operation is one. It can be comprehensively viewed as a non-institutionalised activity involved in the purchase and sale of various forms of livestock. Private sales incur no marketing cost and are likely the cheapest and simplest market outlet.

However, these types of sales typically require a large number of weaner calves to be available to facilitate the transaction. Furthermore, the seller lacks the bargaining power which a livestock auction offers where competition between bidders drives market price.

Livestock auctions are another channel which can be utilised. It is organized by agents and auctioneering companies throughout South Africa. At auctions the sale of animals is done on the hoof and the basic function of auctions is to:

- Advise buyers of auctions and advertise the auction accordingly
- Ensure the smooth running and coordination of the auction
- To duly mark the stock as sold with the corresponding buyer's mark
- Facilitate the transport and loading of stock
- To sell to the highest bidder
- Guarantee the sellers money and verify the creditworthiness of buyers
- Verify the legal ownership of cattle before the selling of it on auction

Due to the services rendered by the agents and auctioneering companies a commission is paid by the seller which differs from company to company. Typically, livestock auctions are collection points where large numbers of animals and species of livestock gather, are bought and sold (Olivier, 2004). One major drawback of such a gathering is the possible transmission of animal disease through the gathering of livestock in one central location and then transported to a different location. This can and has been responsible for the transmission of animal diseases, most notably the transmission of FMD in the Limpopo province in 2019. Both market channels discussed above have their advantage as well as their disadvantages. It is the producer's prerogative to utilise the one which suits them best or even a combination of them.

Specific methods utilised in southern Africa and South Africa to prevent and in the event of an outbreak to contain and control the spread of FMD are:

- Constructing and maintaining fences at great cost to control the movement of wildlife, for example the fences built on the western boundary of the Kruger National Park.
- Movement control of livestock through a permit system which is authorised by the veterinary department.
- Supported by livestock identity and traceability, which entails ear-tags, branding and ear tattoo marks. The enforcement of these is through roadblocks.
- Designated zones have been identified within South Africa according to the potential risk of or currently outbreak. With biannual vaccination of livestock and increased surveillance by the veterinary department in those identified high risk zones.

Several alternative methods facilitating market access are utilised and these methods are as follows:

a) Export zones with vaccination

Export zones are based on the OIE's acceptance that exports can take place from zones recognized as FMD-free with administering vaccines. At present the European Union does not accept this approach from southern Africa. Furthermore, this strategy is technically challenging as well as expensive as all cattle must be vaccinated twice annually. In high risk areas of FMD outbreak due to the proximity of cattle to infected buffalo, such as near the border of the Kruger National Park, this approach may offer a sound alternative, provided it is accepted by importers.

b) Compartmentalisation

Compartmentalisation entails the creation of small exclusion zones at farm level. It requires intensive fencing compliance, quarantine camps, traceability and biosecurity for the different units. Large infrastructure investment is required to comply with the aim of accessing high value markets. This method requires private investment and the state veterinarians' to provide oversight and approval certification. These barriers limit smaller producers from complying and accessing markets. Other concerns have been raised due to FMD's ability to spread via aerosol transmission.

c) Commodity-based trade

Commodity-based trade focus on achieving access to markets by managing the specific risks associated with the products, instead of focusing on total freedom from the disease nationally. For instance, where FMD is concerned products can be procured from healthy animals in conjunction with processing, cooking of products preclude the possibility of the virus being present. In cattle and in relation to FMDV it is required that the bones as well as lymph nodes be removed. An advantage of this approach is the lower veterinary cost as well as the potential to add value to goods through processing.

d) Managing FMD for local trade

The simplest option, which is mostly utilised throughout most of Africa, is responding to outbreaks of FMD if and when they occur and focusing on local markets instead of export markets. With Cape buffalo which is a main carrier and is prevalent throughout Southern Africa, FMD outbreaks are inevitable as it is endemic in the wildlife population. This low cost option mainly benefits poorer, mixed crop livestock farmers which typically would not benefit from export markets (Moerane *et al.*, 2010).

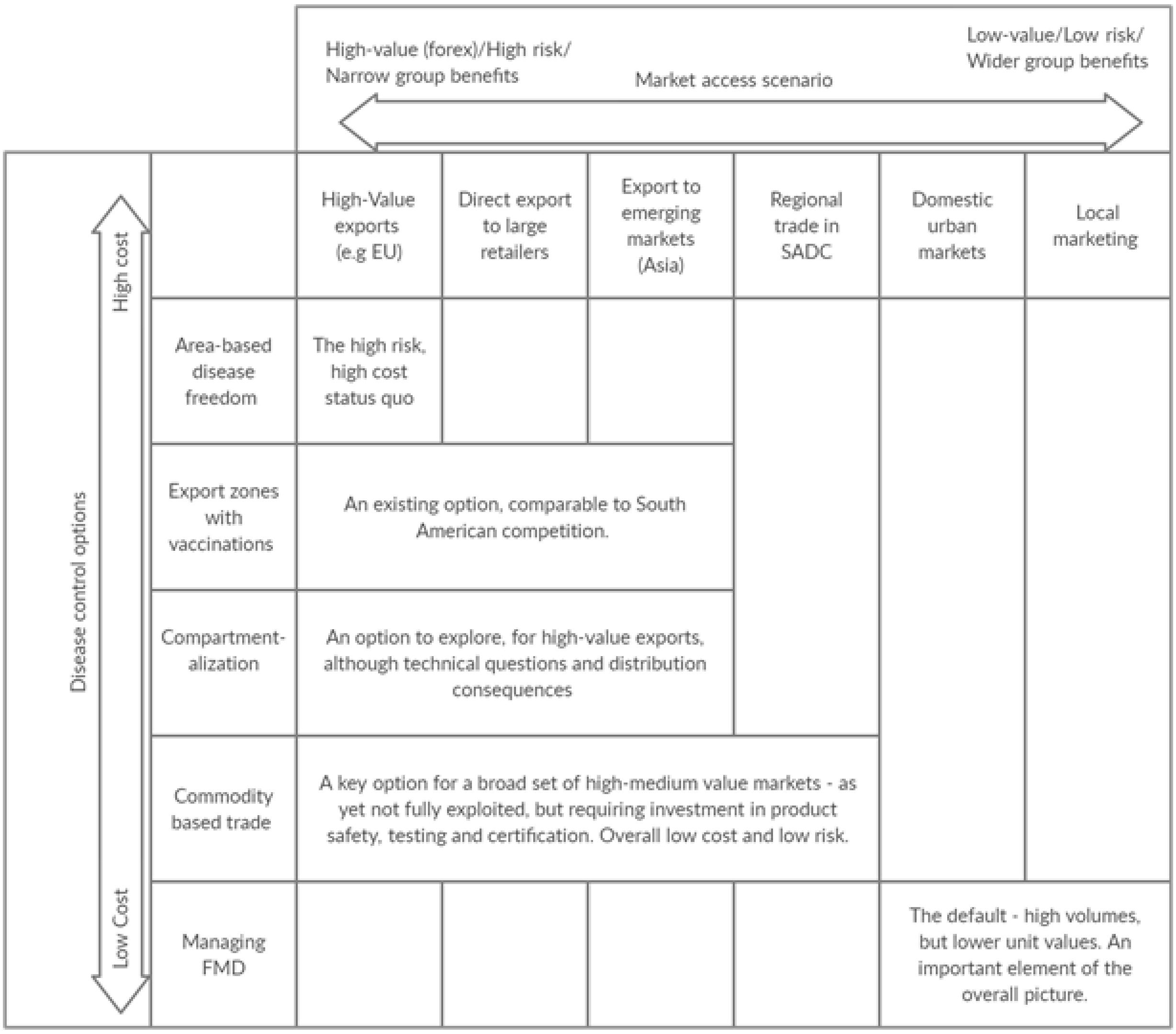

Figure 3.6: Market access and disease control. Source: Foot-and-mouth disease and market access Source: Adapted from Moerane et al. (2010)

The value which can be placed on achieving and maintaining international market access can be seen as revenue forgone if market channels are closed. Such is the case when an outbreak of FMD occurs as stipulated by the OIE, meaning that the exportation of animals and animal products are closed with specific reference to cattle. As previously stipulated the agriculture sector is a net exporter of agricultural products earning valuable foreign currency and has shown substantial growth over a 10-year period. This holds true for animal products and specifically beef exports. Naturally beef exports are categorised into different sections and subsections based on the harmonised system (HS codes) and their unique tariff codes being either two, four or six digits depending on requirements.

Figure 3.7: South Africa's export value and quantity of meat of bovine, fresh or chilled as well as frozen (HS 0201, 0202) for the period 2008 until 2019.

Source: Adapted from ITC Trade Map (2020)

As can be seen in Figure 3.5 export by value and volume has grown significantly from 2008 to the present and shows a similar trend. The profile of the South African beef market value chain in 2018 stipulated that a possible reason for the sharp increase in the period of 2013-2016 could be due to South Africa being declared foot-and-mouth free (DAFF, 2018a).

During the period under analysis South Africa mainly exported to Africa and Asia. In the 2019 season, the Asian market received the majority of the beef export, with a representative value of 68% and China being the largest importer. During the same year Africa represented a 29.5% market share of South Africa's beef exports. Mozambique is the largest consumer and notably a member of the Southern African Development Community (SADC) which promotes trade between members of these nations. Asia replaced Africa as the largest market for beef in 2017 and has increased its consumption and subsequently its market share (DAFF, 2018a).

3.4 Defining the economic and financial impact of the disease in livestock systems

When assessing the influence, impact or cost of an animal disease, it is of important to specify whether the analysis thereof is financial or economic. Financial analysis involves concepts such as costs and revenue, principles which livestock producers would utilise to calculate profits in conjunction with current market price. An economic analysis is more comprehensive as it incorporates concepts such as non-cash costs, opportunity cost and revenue forgone. A reduced level of production does not only effect the producer but also the consumer which means economic costs have an impact on society (McInerney, Howe and Schepers, 1992).

To better understand the implications of animal disease the impact is defined as direct and indirect. Direct impacts can be seen as the visible and invisible losses sustained. These impacts occur directly on the producer side and thus have a negative effect on production. Examples of visible losses include death and stunting whilst invisible losses can be reduced fertility and a change in herd structure. FMD is also known to cause abortions in livestock, resulting in a cost to the producer as they would need to keep the animal for another year without it producing anything, or cull the animal. The invisible losses incurred are related to abortions and the low fertility experienced in effected animals. Due to lower fertility and abortions it is necessary to have a greater proportion of breeding animals in the herd to achieve a similar output. The invisible cost results in every litre of milk or meat produced there being a greater fixed cost to maintain a larger number of breeding stock (Rushton, 2009).

Economically the indirect costs are more complex and shared between different shareholders, such as national government, agribusiness and individual producers. There are additional costs incurred to control the disease for example drugs and vaccines. More components of indirect costs include revenue forgone, goods denied access to more lucrative markets and the suboptimal production technology (Rushton, 2009). The principle behind control of the disease is that the money invested helps to reduced losses elsewhere by a greater amount than that invested. Thus, the idea is to ensure a situation where the costs of population control are reflected in the benefits experienced by the livestock sector as well as in the wider economy. The fixed costs associated with this are investment in infrastructure, research, education as well as state veterinary services to develop the national animal health system. The variable costs would focus on specific programmes for control and management of outbreaks (Knight-Jones and Rushton, 2013).

Disease control can be classified in four key activities: separation, movement restriction, vaccination and surveillance (Moerane *et al.*, 2010). Separation is an area of great importance in South Africa due to the presence of FMD in wild buffalo populations. The construction and maintenance of fences separating wildlife from cattle are of utmost importance, however costly. On a national level the state veterinary services provide services such as culling, vaccination and outbreak control which are all financed by taxpayers. Surveillance is an ongoing expense as it must be continuous or the risk of an outbreak occurring and spreading becomes too great. Apart from government the private sector additionally spends a significant amount of revenue on the control of FMD primarily through the purchase of vaccines. High disease costs have been experienced due to the above-mentioned factors; however, it has been considered justified in an effort to establish, as well as protect, the valuable livestock export market (Moerane *et al.*, 2010).

McInerney, Howe & Schepers (1992) discussed the principles of loss and economic loss, control expenditure and the measurement of disease costs. The authors distinguish between the term “loss” and “cost” and clarify both. The clarification is crucial as different papers tend to categorise cost components differently which means the result of their impact analyses differs. Loss (L) refers to a benefit that no longer is, for example the death of an animal or a potential benefit which did not realise such as a decrease in production due to an animal becoming clinically infected. Both instances of loss result in a reduced output. Expenditure (E) is the extra inputs in the production process due to the impact of the disease. Expenditure can be expressed in two components; treatment expenditure after the disease is detected and preventative treatment before the disease is present to prevent the impact of the disease.

The impact of disease on animals, modelled in a framework, indicates that the negative effects from an economic perspective is either a loss or an expenditure. Economic cost (C) will occur due to the sum of these two components when a disease is present. The assumption is illustrated by $C = L + E$, where the objective of disease control is to have as small a C component as possible. One should take note that social and environmental costs are not related to the market price, but may be represented in the form of hidden costs (McInerney, Howe and Schepers, 1992; McInerney, 1996).

Bennett (2003) elaborates on the framework developed by McInerney (1996) where the cost of the disease C is defined by two economic components namely loss and expenditure. The expanded framework is similar but defines C as direct disease cost where $C = (L + R) + T + P$.

C Direct disease cost
L Value of loss in expected output due to presence of a disease
R Increase in expenditure on non-veterinary resources due to a disease
T Cost of inputs used to treat a disease
P Cost of disease prevention measures

The term direct disease costs (C) indicates that other indirect impacts of livestock disease are not incorporated in this framework, referring to impact on human health, international trade and animal welfare.

Seven main economic impacts of livestock disease was defined by Bennett (2003) namely:

- Reduction in the level of marketable outputs
- Reduction in perceived or actual output quality
- Waste or higher level of use of inputs
- Resource cost associated with disease prevention and control
- Human health cost associated with the disease or disease control
- Negative animal welfare associated with disease
- International trade restrictions due to disease and its control

For the livestock producer, the resource allocation process is most affected by disease in its simplest form. The relationship between allocated resources is best illustrated through a production function showing the relationship of livestock output and inputs in a developed set of concepts and an economic framework (McInerney, 1996). In the instance of a disease, livestock producers operate on a lower production function being more inefficient than in a situation with no disease. It is unlikely however to attain an entirely disease-free situation and so a realistic production for attainable livestock health is utilised opposed to a perfect health situation. At times livestock can be free from a certain disease due to factors such as disease eradication policies and tight quarantine measures. Great Britain for example was free from FMD between 1967 and 2001.

Due to the highly contagious nature of FMD and the difficulty associated with containing it to an area or population, it creates a scenario where all shareholders face a considerable risk. The actions of one producer will likely affect the risk of an outbreak on another producer's stock, in other words, an externality occurs. FMD control is thus shown to be a public good with positive and negative externalities present. For instance, a positive externality can be created by one or more producer vaccinating their animals against FMD and so being less likely to get infected and transferring the disease on to other producers. Conversely, a producer who does not vaccinate against the disease creates a negative externality as their stock is more likely to become infected and so transfer the diseas, theoretically.

3.5 South African regulations and situation

In November 2019 an outbreak of FMD was reported in a previously FMD free zone in the Limpopo province, 19 commercial properties tested positive. The identified locations included: feedlots, commercial producers, as well as community farms. An estimated 14 000 cattle on these properties were placed under quarantine. All properties which tested positive have been linked directly or indirectly to cattle sold at livestock auctions. Subsequently the Minister of Agriculture, Land Reform and Rural Development, gazetted a national ban on the gathering of cloven-hoofed animals (DAFF, 2019). This included all livestock auctions, shows and similar activities in order to prevent the spread of FMD.

The control measures implemented included movement control, no vaccination and a ban on the gathering of animals. Those premises which tested positive for FMD were immediately placed under quarantine, no movement of cloven-hooved animals was allowed on the premises and strict biosecurity protocols were put in place to prevent the spread of the disease by means of fomites. During the initial stages of the outbreak, all farmers were encouraged to limit the movement of cloven-hoofed animals to determine the extent of the outbreak. Producers are still advised to obtain a veterinary health certificate for their animals to confirm the absence of clinical signs of FMD for animals which are to be moved. Moving cloven-hoofed animals and their products out of FMD controlled zones in Limpopo, KwaZulu-Natal and Mpumalanga are stringent and highly controlled. Vaccination was not utilised as a tool to manage this outbreak and the reason being that outbreaks occurred on defined fenced properties where the spread was caused by the transport of animals. Vaccination may be appropriate when outbreaks spread continuously, especially in communal areas where there are no fenced farm boundaries. A ban on the gathering of all cloven-hoofed animals from two or more properties was put in place on the 4th of December 2019 and lifted on the 18th of February 2020. A key reason for this measure was because all affected properties were linked either directly or indirectly to specific livestock auctions.

Outbreak resolutions include measures such as the slaughter of animals on affected farms and feedlots and the testing of animals on affected premises. Depopulation of farms is supported and slaughter of animals from six weeks after the clinical end point of each farm. Risk mitigation is important and includes the disposal of heads, feet and offal of slaughtered animals. Animals on the infected properties are allowed to be slaughtered after six months has passed since the clinical end point on the premises. Since the 20th of January 2020 more than 11 000 cattle from premises under quarantine have been slaughtered. Consideration is given to premises other than feedlots, including those breeding animals in separate groups. Attention is also given to factors such as the separation of groups on the farm, how the premises became infected and the intended future of those animals. Control is a combination of the removal of affected groups, depopulation and serological testing of animals (DAFF, 2020b).

Government Gazette Republic of South Africa Vol. 65 4 December No.42883
ANIMAL DISEASES ACT, 1984 (ACT NO. 35 OF 1984)
CONTROL MEASURE RELATING TO FOOT-AND-MOUTH DISEASE IN CERTAIN AREAS

The objective of control measures.

The objective of the control measures is to prevent the spreading of the foot-and-mouth disease virus. The spread thereof is commonly occurs through gatherings of live cloven-hoofed animals, including auctions, shows, speculators or any other activities for which live cloven-hoofed animals are physically brought onto a piece of land or property from two or more places of origin. This is done in order for the animals to be re-distributed to two or more places or destination by means of sale, barter or any other purpose. Unless such live cloven-hoofed animals are kept on the piece of land or property for at least 28 days after arrival, there may not be any new introductions, before being distributed to other pieces of land or property as proven by auditable records to be kept by the owner or manager of the land or animals on the land (DAFF, 2019).

Prohibition on the live auction of cloven-hoofed animals

Any activities for which live cloven-hoofed animals are physically brought onto a piece of land or property from two or more places of origin in order for the animals to be distributed to two or more places of destination by means of sale, barter or any other purpose are prohibited in the whole of the Republic.

Any person who suspects or becomes aware of any activities for which live cloven-hoofed animals are physically brought onto a piece of land or property from two or more places of origin in order for the animals to be distributed to two or more places of destination by means of sale, barter or any other purpose in the whole of the Republic must report this to the responsible State Veterinarian immediately.

Activities and pieces of land or property that ensure that live cloven-hoofed animals are kept on the piece of land or property for at least 28 days after arrival, without new introductions, and before being distributed to other pieces of land or property are exempted from 3.(1) provided the owner or manager of the land or the animals on the land keeps auditable records of the stay of each such animal for at least 5 years in the format as prescribed by the director (DAFF, 2019).

There are some notable additions and interpretations to the government gazette to focus on, for instance the premises where cloven-hoofed animals are brought together from two or more locations and then re-distributed to two or more locations, are specifically mentioned. The prevention of gatherings is binding for all provinces; however, there is no ban on the movement of livestock, although it is discouraged in order to prevent the spread of disease. Additionally, the movement of animals from one property to another is outside the scope of the Gazette Notice.

In terms of the sale of animals the movement of animals from the farm or feedlot to the abattoir is permitted, as the abattoir is an end point destination from where live animals will not be distributed. On-farm sales of livestock are permitted, under certain conditions, namely:

- No clinical signs of FMD on the property
- The state veterinarian is notified and is in agreement to supervise the process
- Auditable records must be provided that show all animals on the premises have been there for at least 28 days
- No additional animals have been added during this 28-day period

Controlled areas

The term “controlled areas” is used to be consistent with current legislation. The subdivision of South Africa into designated FMD control zones is undertaken and demarcation is based on epidemiological factors, fences, species, the environment and ecological factors. South Africa is divided into 3 distinct FMD control zones as follows:

Infected zone

OIE definition: The infected zone is defined as zone in which a disease has been diagnosed (OIE, 2020). The infected zone is clearly defined geographic areas in which FMD is endemic, due to the presence of the FMD carrier, cape buffalo (*Syncerus caffer caffer)*. In such a zone:

- The routine vaccination of cattle is practiced
- Strict movement control of live animals and products is applicable
- Intensive FMD surveillance is conducted

Protection Zone

As per the OIE definition: A protection zone refers to an area established to protect the health status of animals in a free country or free zone, from those in a country of a different animal health status, using measures based on the epidemiology of the disease under consideration to prevent the spread of the causative pathogens agent into a free zone or country. The measures include, but are not limited to, vaccination, movement control and an intensified degree of disease surveillance.

Nationally the protection zones are considered as areas outside the free zone and are thus considered “infected zones” as per OIE definition. Accordingly, movement control measures are applied from these zones to free zones. Protection zones are not part of the FMD free zones and are further subdivided into two zones, namely:

- Protection zone with vaccination.

These refer to clearly defined geographic areas adjacent to the infected zones. Routine vaccination of cattle for FMD is administered. Only FMD free buffalo can be kept and the owner or manager is required to implement proper fencing and testing at their own expense. There is strict movement control of products and of live animals and intensive FMD surveillance.

- Protection zone without vaccination.

This is clearly defined as geographic areas adjacent to the free zone and international boundaries. Conditions are as with protection zone with vaccination however no vaccination occurs as implied. No FMD vaccination is practiced.

Free zone

The OIE defines it as: A zone the requirements specified in this Terrestrial Code of Free Status as been met, thus demonstrating the absence of the disease under consideration. The appropriate veterinary control must be applied for animals and animal products as well as their transport within this zone and its borders. Clearly defined geographic areas comprising the entire country excluding the infected and protected zones. No FMD vaccination is practiced. The free zone includes the highly surveillance areas.

3.6 Socio-economic impact

The South African livestock industry comprises both commercial producers as well as subsistence producers and so the economic implications differ depending on the producer's situation. FMD is perceived to be a trade sensitive disease although this perception appears to be conflicting with socio-economic practices. For instance, rural/communal producers are unlikely to benefit from international export markets and are highly dependent on state veterinary services for vaccinations to maintain their livestock health. Livestock are held for different reasons such as ceremonial use, ploughing, food and dowries (lobola). Therefore, communal farmers' perception of value differs from that of a commercial farmer's and so does the impact that the disease has on them.

FMD disease remains one of the most potentially harmful livestock diseases in existence today. It has direct implications on the producers and indirect implications on the livestock industry. The prevention, monitoring and control of the disease are of paramount importance in order to protect the live animal export market. The potential impact must be considered when planning and financing disease control (Otte, Nugent and Mcleod, 2004).

3.7 Herd structure

Year-round breeding

In herds where breeding takes place throughout the year, bulls are typically left with the cow herd all year-round. Heifers are then added to the herd once they are old enough and large enough for mating. In this type of system, the herd typically tends to fall into a natural calving cycle of their own, with the majority of calves being born in spring. This being in a summer rainfall area (DAFF, 2000; Smith, 2006).

Advantages of year-round breeding

- Marketing can occur throughout the year.
- There is less management of the bulls and they don't require a safe separate area to be away from the herd.
- Fewer bulls are required as a smaller proportion of cows come on heat at a time.
- Cows are served as they commence cycling after calving, no waiting for bulls to be added to the herd.

Disadvantages of year-round breeding

- They have high nutritional requirements throughout the year to ensure an adequate conception rate which is most challenging during winter months.
- Herd management tasks such as; dehorning, castration, ear marking and vaccination must be conducted year-round.
- The replacement of old cows and slaughter becomes complex, especially as it occurs at different times of year.
- There is a high degree of herd management to achieve adequate calving percentages.

Fixed breeding season

The timing of the calving season is determined by the date on which bulls are added to the cow herd; however, breeding will only commence when cows are coming on heat regularly. Spring breeding then commences when the cow comes into cycle, but this can be delayed due to poor nutrition during the winter or summer. Poor management such as overstocking or leaving the weening of calves too late can cause poor body condition which takes longer to recover from and subsequently longer before breeding can occur again. Good practice is to have calving begin 4-6 weeks before the spring rains, then mating will begin 6-8 weeks after the first rains.

Advantages of a fixed breeding season

- Herd management and fodder flow is simplified. Dehorning, castration, ear marking, and vaccination can be done over a shorter period of time which leaves time for other activities.
- It is easier to monitor the herd's conception rate and detect cows which do no calf and must be removed from the herd.
- Animals can be marketed in uniform groups.
- Herd management is simplified, allowing for more informed management decisions and control over the herd.

Disadvantages of a fixed breeding season

- If a cow does not cycle whilst the bull is in the herd, she will not produce a calf and thus lose a year in the production cycle.
- Bulls must be kept in a separate area away from the herd when not in the breeding season which requires resources and management.
- Heifer management is increased as they must be kept in a separate herd.

3.8 Conclusion

The impact of animal diseases is multi-faceted and FMD is no exception. It can be seen from a national, industry as well as producer level. On each level the effect thereof is different. The literature reviewed relating to FMD encompasses multiple aspects. The agricultural sector's contribution to national GDP has proportionally been decreased compared to the other sectors; however, it has increased significantly in value since 1970. For trade to occur market access is crucial and is one aspect in which FMD is highly detrimental. The closure of live auctions nationally reduces market access to producers and causes disruptions in the value chain. The production system, market access and alternative methods to allow for market access were discussed. The financial as well as economic aspects of FMD are part of animal health economics. The national regulations put in place due to an outbreak occurring, provides both the parameters as well as the timing of when an outbreak occurred. This information in turn allows for the model design and construction as is discussed in Chapter 4.

Chapter 4: Theory and structure of the models

4.1 Introduction

Industry and animal disease related situations are discussed in Chapter 3. This chapter aims to describe the development of models which are to be used to explore the financial implications of FMD outbreak and control. The two different situations modeled are described and constructed, each representing a distinct herd structure for the same typical farm. The simulations are based on the control strategy for the spread of FMD which includes the closure of live animal auctions. A brief overview of the theory which supports systems thinking, systems modelling, and typical farm theory is presented. The development phase as well as the general assumptions used for the development of the respective models simulated is explained.

The systems thinking approach and strategic farm planning are discussed in terms of the need for integration. The theory regarding the use of a typical farm as well as farm budgeting is described as well. The model's structure, parameters, construction and financial results are presented. Distinction will be made between the two constructed models. A herd structure with a fixed breeding season is described and illustrated and secondly a herd structure in which a year-round breeding season is simulated is described. The chapter concludes with simulations discussed in order to explore the financial implications of the control strategy for FMD.

4.2 Systems thinking approach

Systems in layman's terms are a group or combinations of interrelated, interdependent, or interactive elements forming collective entities.

The world is continuously changing, with rapid growth, globalisation, increased trade and technological advances it is becoming increasingly connected which in turn results in the rapid growth of complex systems all around us, whether they are noticeable or not. In essence systems are connected and feed into each other, producing complex effects. The legislation and farm management implications of a FMD outbreak, is a good example of an external effect on the farm operational system. Systems thinking can be utilised to better understand complex relationships and behavior, in order to explore outcomes and potentially change them. With the dawn of globalisation and thus interconnected markets where one action can have a far-reaching ripple effect, it can be argued that all people in a decision-making capacity should have a working understanding of systems thinking.

Though in practice not all systems have a clear goal or objective, however systems thinking does. For this purpose, systems thinking is defined as a goal orientated method, in order to achieve a desired outcome (Nuthall, 2011; Arnold and Wade, 2015).

Systems thinking

Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, projecting their behavior and formulating modifications in order to produce desired effects. These skills work together as a system (Arnold and Wade, 2015). Even though individual elements of systems thinking are identified and described in order to better understand the system, the core concept of systems thinking is not to isolate components, but like in the occurrence of FMD, must be explored within a whole farming system and not in isolation.

Some of the elements of systems thinking are described below.

Recognising interrelationships:

This refers to the key connections between parts of a system, the greater the number of components, the more complex.

Identifying and understanding feedback and causal connections between components:

Components may affect one another in any number of ways, as prelude to the more connections, the more complex. Causal feedbacks occur where a change in a component affects others which will eventually feedback to the original component.

Understanding system structure/boundary:

This refers to elements and their relationship with each other which facilitates system behavior.

Differentiating types of stocks, flows and variables:

Stocks refer to the pool of a specific resource within a system. This can be either physical or emotional, with feed being an example of physical. Flows refer to the changes in the levels of the resources. Variables are parts of the system which relates to stock and flow, for example the rate at which they are consumed. In agriculture for instance the rate at which feed is used to fatten cattle. In laymen terms these can be simplified to input and outputs utilised.

Identifying and understanding non-linear relationships:

This includes stock, flow and variables which are of a nonlinear nature. A change in a system can produce an effect which is disproportionate to its size, thus small changes can create a large effect and vice versa.

Understanding dynamic behavior:

Interconnections combine into feedback loops, which influence and consist of stocks, flows and variables create what is called dynamic behavior within a system.

Reducing complexity by modeling systems conceptually:

This is the ability to conceptually model different parts of a system and view a system in different ways. This modeling extends beyond the scope of defined systems models and focuses on simplification using reduction, transformation and homogenisation. Theoretically this would allow for the interpretation of greater complex systems, as the less complex has less detail on each part. Put plainly, this skill entails the ability to look at a system in a number of ways, stripping it from unnecessary excess, reducing its level of complexity.

Systems thinking acts as a tool to facilitate system dynamics and system simulation in order to better understand physical and social systems. If systems thinking can lead to a better understanding dynamic and modelling, then a positive more accurate output can be achieved.

System dynamics and system simulation

System dynamics is part of systems thinking and attracts more interest due to its ability to mimic the real world. It can incorporate complex, feedback loops, linear and non-linear structures found in physical and social systems. The goal is to move from a problem to a solution by understanding the system. A main problem is the lack of guidance moving from a real-life situation to a simulated model (Forrester, 1994). There are farm management problems which exist in practice which cannot be solved using well-structured analytical techniques such as gross margin analysis and linear programming. To solve these problems, it is necessary to develop a model designed specifically to represent and solve such a problem. Budgeting is a simple form of simulation as it models a farming system. A specific budget is constructed for a unique situation. Once constructed a budget can be used to experiment by changing various parameters and comparing the results of those changes (Nuthall, 2011).

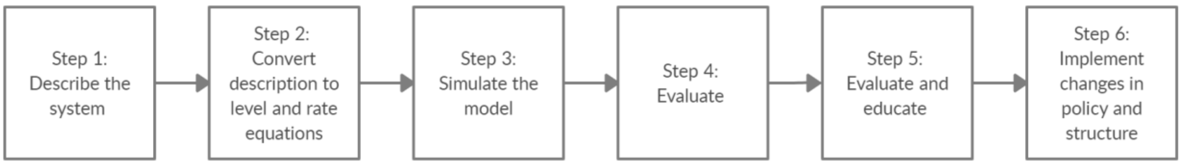

Figure 4.1: System dynamic steps from problem to improvement

Source: Adapted from Forrester (1994)

When referring to step three, simulate the model, there is no way to prove the validity of a theory which is proposed to represent the behaviour of events in the real world. A degree of confidence in that model can only be achieved between a trade-off of adequacy, time and cost of further improvements. Given enough of each the model could be changed indefinitely as there is no correct answer per say. A proposed basis of comparison for a model would be between itself and the scenario which would have otherwise been used in its place. The clarity generated in the real world by system models due to the simplification of large complex systems is valuable. This is especially in situations where time crunches, budget pressure and improved performance are key areas of operation (Forrester, 1994). No set rules exist in system simulations, the method is a general approach where each problem requires a model specifically designed for that particular case (Nuthall, 2011).

4.3 Strategic farm planning

Strategic planning is used when making important managerial decisions in a farming enterprise. Be it over the short or long term. Short term decisions focus on operational aspects, decisions which aim to exploit opportunities which arise to reduce the impact of adverse conditions. Long term decisions on the other hand are in line with the long-term goals of the farming enterprise, highlighting the importance of planning, to facilitate the decision making process(Louw, Geyser and Jordaan, 2017). The production of agricultural goods within a farming system is complex and inherently risky. Risk can be attributed to both abiotic and biotic factors and affects the production process as it is not a closed system. Livestock production, like most other agricultural goods, occurs in an ever-changing natural environment in which exogenous shocks to the system are common.

A key reason for researchers and specifically agricultural economists to study farm level production systems, is that the information obtained from the modeled system can be used to improve decision-making (Strauss, Meyer and Kirsten, 2010). When starting to examine a farm system, it should incorporate all possible conditions and background factors in which the system operates, including those from a broader economic perspective. In order to complete the analysis, a typical representative farm for the specific industry should be constructed and analysed, with the aim to improve decision-making. Given the complexity and risk associated with farming systems, a multi-disciplinary approach is required in order to correctly and accurately portray the systems and its individual components. In order to quantify an environment and situation in determining what the impact of changing variables would be on it, system systems thinking is applied because it enables the simplification of complex systems within a typical farm, specific farm, or a case study.

The aim of this study is to evaluate the impact of animal disease, specifically FMD, on commercial beef cattle production systems. One system will make use of a fixed calving season and the other system will be without a fixed calving season. Complexity occurs due to the series of interrelationships found in each system that function in order to reach a common goal. Complexity is a factor of components and relationships that create structure and function. When a factor is added as in this instance with FMD, the structure and functionality can alter. In this case it influences herd structure and activities. In this study, several farm systems are involved which consist of various components. In the system, a change to one component will invariably impact other components and extend to the entire system. For this reason, a method is required that will capture the interdependent nature of components and is able to show the extent to which a change in one component will impact the system. The impact is measured in profitability and cash flow. A quantitative and positive approach is followed in this study, meaning it must be as close and accurate to reality as possible.

4.3.1 Typical farm

For a farming system to be evaluated there must be a study unit in the form of a typical farm, case study or specific farm. This will also serve as the system boundary. A typical farm is used for this study and it will act as a representative farm which shares similar characteristics to a large number of farms. This requires the incorporation of production and non-production factors. Some of the most critical considerations are farm size, market access, ownership, debt, farming practices and profitability. The concept of a typical farm as stated by Feuz et al. (1990) is not a leading farm, far ahead of most, not equipped with the most modern technology and equipment, but well equipped and well managed. The representative farm is one that is typical of the group of farms which are being represented, not necessarily the mean of the farms in the group represented but a model concept (Nuthall, 2011).

Representative typical farms can be used to analyse a range of problems and scenarios. Some examples of these are:

- To evaluate the impact of government policy measures.
- To determine improved farming systems.
- To estimate product supply functions (indicates the quantity that would be produced given the producer receives various prices).
- To demonstrate various management aspects.

The advantages of using representative typical farms are:

- Realism. As the represented farm is a real-world situation the portrayal thereof will be more accurate as opposed to a hypothetical farm where several assumptions would be required.

- Objectivity. Comparisons can be made with alternative farming systems; thus, the selection of an improved system is completely objective.
- Detail. It can be as detailed as required. Emphasis is placed on developing the technical production relationship and subsequently constructing improved systems from this information.
- Variation in planning parameters. Based on basic technical relationships, the variation in cost and price can be readily calculated. Additionally, the same can be said for production and input/output parameters.

The results of the analysis have a higher probability of being realistic, opposed to for example a case study. Additionally being able to generate interest from producers as they are able to make direct comparison between the analysis and their own situation.

The disadvantages and problems of representative typical farms are:

- Large homogenous areas are desirable. For the generated results to have meaning it is desirable to have a large group of similar producers for whom it is applicable.
- The generality of results. Each farm is unique and so the direct application of results from one situation to another is not accurate, which highlights the importance of selecting similar or typical farms where similarities occur.
- Lack of statistical significance.

4.3.2 Farm budgets

When making farm management decisions, budgets are useful tools. Budgets are expressed as written plans which incorporate physical as well as financial quantities through the coordination of resources, production and expenditure. Both the budgets and assumptions on which they are based, are subject to change. It does not provide an accurate picture of what will happen but rather of what the potential outcome could be. The main objectives of budgets are:

- Planning a farming system and its subdivisions.
- Comparing various production plans.
- Determining capital requirements and make investment decisions.
- Planning cash flow position in order to obtain credit if necessary.
- Serve as a basis for comparison over time.
- Stimulate and support critical thinking.

The study makes use of farm budgets to achieve the following summarised goals.

- To accurately represent a typical productive and profitable commercial beef operation using two unique production systems.

- To create whole-farm multi-period budgets on the past three years.
- To determine the associated cost and revenue components of the operation.
- To determine the cash flow component of each production system on a monthly basis and determine business health estimates in order to assess credit access if needed.
- To apply scenario analysis to budgets.

Farm budgets serve as research method in answering research problems. A wide variety of budgets exists for agricultural application but differ depending on purpose. The most common form of budget is whole-farm, cash flow, partial and enterprise budgets. The type of budget selected is dictated by the question which it needs to address, such as the requirement of external capital for the expansion of an enterprise (Hoffmann, 2010).

A whole-farm budget is generally constructed on an annual basis and includes all income and expenses occurred during that period. It summarises the major physical and financial features of the enterprise. An extension of this form of budgeting is whole-farm multi-period budgeting, which allows budgeting for several seasons. A key benefit of this kind of budgeting is the ability to calculate the internal rate of return (IRR) on capital investment as well as the net present value (NPV). Some adjustments to the standard model are required to enable these calculations. A cash-flow budget deals with the timing of income and expenditure in the production period. Cash-flow budgets are typically constructed on a monthly basis and provide those in management with information on operational credit, repayment as well as time and amount of borrowing. The construction of budgets can typically be completed in spreadsheet programs such as Microsoft Excel, which was used in this study. The complexity of budgets completed in spreadsheets lies in the number of variables which can be interconnected. Systems thinking enables the identification and understanding of these interconnections (Louw, Geyser and Jordaan, 2017).

4.4 Location, identification and validation

The specific focus of this project is to determine the financial effect of a FMD outbreak on farm level. The effect is thus general and allows for a simulation of the expected effect over a large geographical area. The selected farming area on which the models are based, were selected to fulfill several specifications. It is also an area which falls outside any FMD protection or surveillance zone and is free of any FMD outbreaks. The area is suited to and representative of extensive livestock farming where livestock is the main agricultural product produced and makes a notable contribution to the livestock industry. The Vryburg area of the North West province was selected for this purpose. The area is predominantly a summer rainfall area, considered to be semi-arid with an annual average rainfall of 450mm (South African Weather

Service, 2018). As discussed in Chapter 3.2 the North West province contains an estimated 12% of the national cattle herd, the 4th largest provincial contributor in the country. Prices relating to the monthly average price paid nationally for each animal class was sourced from the Red Meat Producers Organisation of South Africa (*Weekly Prices – RPO*, no date).

The development and validation of the typical farm model was done in consultation with various producers and role players within the industry. They are knowledgeable with regards to the industry and production systems as well as the general location in which the typical farm model was constructed. The following individuals were consulted:

- Jood Cloete Producer and marketing agent KLK Upington
- Johan Lambtechs Producer, Kuruman district
- Flip Hoffman Producer, Gordonia

4.5 Model construction, segmentation and description

The models replicate two herd structures, one with a fixed breeding season and one without. The process through which the model is constructed occur in several distinct, however interconnected components. The first component of the model simulate the basic system of profitable commercial beef cattle enterprise in an extensive production system over several production seasons. The second component simulates the cash inflow and outflow based on the production of beef weaner calves simulated in the first component. The third component simulates the production effect FMD has on a beef weaner production herd, by simulating the closure of live animal auctions over extended periods of time. The fourth component models the change in cash flow and production costs as a result of FMD and the extended simulated closure of live animal auctions.

4.5.1 The production simulation component

The first components of the model simulated the basic system of a profitable commercial beef cattle enterprise in an extensive production system over several production seasons.

Parameters

A whole-farm multi-period budget is constructed to include various components. As the name suggest it runs over more than one year. The reason for this selection is that disease, drought and other factors have a multi-year impact on the enterprise. Due to the nature of production, structural changes in the herd require an extended period. Long term investment is also required to achieve these goals and thus a multi-period budget is required. The budget is constructed for a three-year period which represents three production cycles in a fully functioning beef herd.

The physical dimension of the farm model includes land area and is expressed in hectares and categorised according to their use. Developed land refers to that on which fixed improvements have been made such as sheds, roads and housing. Natural pasture refers to that in which animals are grazed through the year. Successful pasture management involves determining the carrying capacity and setting a proper stocking rate. Pasture carrying capacity ultimately dictates how many animals can be kept sustainably. The stocking rate in the area selected for the analysis is one large stock unit per 10 hectares of pasture.

The value of land is based on several economic, social and biological factors. The prices used to represent land value were as close as possible to market-related prices for a typical farm. Ownership of the typical farm is assumed to be as a sole proprietor, or alternatively family-run business. The owner is directly involved in the management, operation and financing of capital. It is assumed that it is for bonafide farmers. This specific ownership structure was selected because a large number of farms are structured this way.

Inventory

The inventory is the statement in which physical assets belonging to the farm business and their money value are recorded. The numbers and quantities are recorded. The money value of assets is calculated by valuation and allowance is made for depreciation. The method used to determine the value of assets, is the book value method. Accumulated depreciation is deducted from the original purchase price of the asset. Depreciation, if not otherwise stated specifically, is calculated using the straight-line basis.

The inventory components account for medium term assets and fixed assets. Medium term assets include implements, tools, equipment, vehicles and machinery. Fixed assets account for fixed improvements and farm-related fixed improvements. The inventory does not account for current assets as these are considered to be consumable items such as fuel and feed, used in a typical production of one year. These consumable items are considered elsewhere as inputs and outputs.

Equipment varies from farm to farm, depending on individual preferences, unique situations and availability of support services, of which support servicing for tractor and vehicles are a prime example. However, similarities exist between the basic requirements for a farm to operate successfully and these must be accounted for. The distinction between fixed and medium-term assets is that it has a useful expected lifespan longer than 10 years. Fixed improvements differ from farm related fixed improvements as they are not directly utilised in the production process, for example the farmer's house. Farm related fixed improvements are directly involved in the production process, such as a shed. Livestock makes up the final components of the inventory. Breeding stock is valued in the same way as machinery, that being cost price or the replacement value less accumulated depreciation.

4.5.2 Amortization/Capital requirement

For long term financing it is assumed that the owner of the farm makes use of both their own, as well as borrowed capital. Borrowed capital can be obtained either from commercial banks or the Land Bank, subject to credit evaluation. Factors which affect credit valuation are:

- The farm business' previous financial performance.
- The farm business' current financial performance.
- The farm business' future financial performance.
- The security position.
- The industry.
- The credit record of the lender.

A critical factor when making use of borrowed capital is the ability for the business to maintain liquidity and the capacity to absorb setbacks. The farm should be able to continue with its farming operation despite unforeseen circumstances. In doing so means the business would be able to finance all its obligations without having to resort to emergency measure such as the sale of breeding stock.

The assumption made in the model is that the land component is inherited. As an extension for the fixed improvements on it, finance is required for machinery, implements, workshop tools, livestock and vehicles. It is assumed that 25% of movable capital will be borrowed capital and the remaining 75% is own capital. A direct link exists between inventory and amortization as the borrowed contribution is calculated from the total capital cost of inventory once depreciation is accounted for. The amortization table is utilised in order to calculate the principle, installment and rent, whilst setting the parameters of term and real interest rate.

4.5.3 Herd structure

As previously discussed, two herd structures are modeled separately, one with a fixed breeding season and the other without a fixed breeding season. These two herd structures are simulated on the same base farm. Both models are simulated as their marketing strategies differ and thus the impact of FMD on the financial component of the business will differ. From a technical aspect it is necessary to outline basic farm level production assumptions and incorporate them into the model. The herd structures modeled is that of commercial producers opposed to stud producers, as the technical aspects of production as well as the marketing of these systems differ.

The number of animals in the core cow herd is the most important production variable. This is attributed to the fact that other variables are based on a percentage of the cow herd. In Table 4.1 the size of the cow herd is shown as 600 animals. Based on this number it is possible to calculate other important variables such as the number of bulls required as well as the number of calves produced.

Table 4.1: Parameters pertaining to herd structure and production

September 2017- August 2018	
Cow herd	600
Bulls	4.00%
1st calf	15.00%
Replacement	17.50%
Calving % of herd	80.00%
Calving % 1st calf	100.00%
Calf retention	15.00%
Dry cows	20.00%
Calving period	Sept-Oct-Nov

Assumptions applicable to the herd and production process:

- The number of the cows in the main cow herd remains constant for each simulated year.
- Replacement heifers are retained each year from the calves produced.
- A production cycle runs from September to August of the following year.
- Marketing weigh of weaner calves is 240kg.
- Pregnancy checking of all 1st calf cows is done, and non-pregnant animals sold.

In beef production breeding, and consequently calving, is managed in accordance with the individual producer's production plan. Breeding can take place throughout the year where no calving season is utilised, or it can be restricted to a predetermined time of the year. Both systems have key advantages as well as disadvantages as discussed in Section 3.7. The choice of system lies with the producer's preferences and the unique situation of the farming enterprise and its location. The timing of breeding dictates when calves will be produced and when they are marketable to generate an income for the business. Weaner calves are the main source of income. Timing is thus a critical part of production as well as cash flow management. Timing is also a concern in the event of a FMD disease outbreak. Naturally it can occur at any time as it is uncontrolled but depending on a producer's herd structure the impact can differ. The closure of live animal sales as part of the control strategy for FMD is an example of this. As can be seen in Table 4.2 and Table 4.5, live animal auctions were closed during December 2019 and January 2020 and so no price value is displayed during that period. The timing of an outbreak and the length of time in which control measures are put in place, play a critical role in the production process and cash-flow management.

Fixed Breeding season

A fixed breeding season is achieved by allowing bulls with the cow herds at a specific time of year. The aimed result is calving for the entire herd to be roughly at the same time period and then subsequently the weaning and marketing of those calves as well. In a summer rainfall area, on which the model is constructed, spring is the optimal time for the cow to calf. Mating will be in the summer and to raise a calf to an acceptable weaning weight. Table 4.2 graphically illustrates a summer calving season for the control scenario. The monthly quoted prices are additionally displayed in the figure, this is done to allow for a better understanding of the implications. This structure and information will again be presented in the following chapter.

Calving begins in September and continues till November. Those calves stay with their mother on natural grazing until March. Weaning of calves occurs in April and May. Replacement heifers are selected at weaning and retained while all other calves are then sold. Bulls are added to the herd from November till February for mating and production in the following season. Uniformity among calves in terms of age and weight are normally a result of this kind of production system.

Table 4.2: Fixed breeding season herd structure

Prices (R)	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
A2/3	45,78	45,78	44,70	44,62	45,03	46,18	43,97	45,74	43,68	43,78	43,69	43,79
B2/3	39,01	39,16	40,15	39,91	41,63	41,94	43,83	41,42	39,71	39,73	40,62	40,52
C2/3	37,10	37,04	37,04	37,58	39,11	40,19	40,25	39,41	37,99	38,51	38,80	39,24
Weaner	28,90	29,22	26,27	Closed	Closed	33,52	32,84	29,17	29,85	29,97	32,04	32,88
	September	October	November	December	January	February	March	April	May	June	July	August
Bulls			Bulls with cow herd									
Cows			Mating period									
Calves	Birth/Calving							Weaning				
Bulls	24	24	24	24								
Cow herd	600	600	600	600	600	600	600	600	600	600	600	600
Lactating cows	480	480	480	480	480	480	480	480	480	0	0	0
Dry cows	120	120	120	120	120	120	120	120	120	0	0	0
Cow herd calves (0-8 months)	480	480	480	480	480	480	480	480	480	0	0	0
1st Calf cows	90	90	90	90	90	90	90	90	90	0	0	0
1st Calf calves	90	90	90	90	90	90	90	90	90	0	0	0
Replacement Heifers (9-20 months)	105	105	105	105	105	105	105	105	105	105	105	105
Total calves	570	570	570	570	570	570	570	570	570	0	0	0
Sales						15	5	465			90	

Table 4.3: Fixed breeding season sales value

Gross income from sales (A)	Quantity-mortality	Mass (kg)	Total mass (kg)	Dressing (%)	Dressed mass (kg)	Price (R/kg)	Total income (R)	Per animal (R)
Bulls	5	750	3528	58%	2046,24	40,25	82361,16	17508,75
Cull cows	88	450	39690	50%	19845,00	39,24	778717,80	8829,00
Heifers not in calf	14	400	5762,4	50%	2881,20	41,94	120837,53	8388,00
Weaner	456	240	109368	100%	109368,00	29,17	3190264,56	7000,80

Fixed breeding season sales

The farming enterprise generates revenue through the sale of livestock. This includes the sale of weaner calves to live animal auctions and also the sale of cull bulls, cull cows and heifers not in calf, directly to abattoirs for slaughter. Table 4.4 illustrates the quantity and rate of sales for the control scenario. For instance, 20% of bulls are sold each year resulting in an actual quantity of five bulls. These bulls are replaced again in September as indicated in chapter 5. The quantity of weaner calves to be sold is calculated by the total number of calves produced minus the number of heifer calves retained which are used as replacement heifers in the herd.

Table 4.4: Fixed breeding season sales quantity

Sales	Rate	Quantity
Bulls	20,00%	5
Cull cows	15,00%	90
Heifers not in calf	14,00%	15
Weaner	Total calves - replacement heifers	465

Mortality is a factor which must be accounted for when working with livestock. A two percent mortality is thus accounted for between the quantity of sales in Table 4.4 and the calculation of the sales value in Table 4.3.

The sales value is calculated in Table 4.4. Bulls, cull cows and heifers not in calf are sold to an abattoir to be slaughtered. The criteria by which the cattle are graded are according to age (AAA being young, ABAB, BBB, or CCC being the oldest) as well as the fat class (000 being the lowest and 666 being the highest). The price differs depending on these factors and is calculated on dressed mass. Prices vary throughout the year and timing of slaughters will have an impact on income. The sale of weaner calves at live animal auctions is on the hoof basis. Price is determined by auction and so the success thereof would be dependent on the quality of the animals on sale, the number and participation of the buyers.

Breeding throughout the year / Year-round breeding

In this system, bulls are in with the cow herd year-round. In terms of breeding, bulls mate with the cows as soon as they come into the ovulation cycle again. This is not necessarily at the same time for all cows in the herd as with a fixed breeding season. However, herds tend to fall into a cycle where calves tend to be born in the spring. In this system calves are born year-round and in terms of marketing there is potential to sell calves at several intervals throughout the year. Table 4.5 graphically indicates the herd structure for the control scenario.

Timing and quantity of sales are two key components of a year-round breeding season. In the case of beef cattle in this system calves are ready to be marketed once they have reached 260kg in mass. With calving in the cow herd occurring throughout the year the age and weights of calves will be widely distributed reaching marketable weights at different times. Table 4.5 indicated weaner calves are sold on several different occasions.

Table 4.5: Breeding throughout the year herd structure.

Price (R)	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
A2/3	45,78	45,78	44,7	44,62	45,03	46,18	43,97	45,74	43,68	43,78	43,69	43,79
B2/3	39,01	39,16	40,15	39,91	41,63	41,94	43,83	41,42	39,71	39,73	40,62	40,52
C2/3	37,1	37,04	37,04	37,58	39,11	40,19	40,25	39,41	37,99	38,51	38,8	39,24
Weaner	28,90	29,22	26,27	Closed	Closed	33,52	32,84	29,17	29,85	29,97	32,04	32,88
	September	October	November	December	January	February	March	April	May	June	July	August
Bulls	Bulls with the herd											
Cows	Mating period											
Calves												
Bulls	24	24	24	24	24	24	24	24	24	24	24	24
Cow herd	600	600	600	600	600	600	600	600	600	600	600	600
Lactating cows	480	480	480	480	480	480	480	480	480	480	480	480
Dry cows	120	120	120	120	120	120	120	120	120	120	120	120
Cow herd calves (0-8 months)	480	480	480	480	480	480	480	480	480	480	480	480
1st Calf cows	90	90	90	90	90	90	90	90	90	90	90	90
1st Calf calves	90	90	90	90	90	90	90	90				
Replacement Heifers (9-20 months)	105	105	105	105	105	105	105	105	105	105	105	105
Total calves	570	570	570	570	570	570	570	570	480	480	480	480
Sales						15	5				90	
Weaner	91				91	91		182				91

Table 4.6: Breeding throughout the year sales value

Gross income from sales (A)	Quantity-mortality	Mass (kg)	Total mass (kg)	Dressing (%)	Dressed mass (kg)	Price (R/kg)	Total income (R)	Per animal (R)
Bulls	5	750	3528	58%	2046,24	40,25	82361,16	17508,75
Cull cows	88	450	39690	50%	19845,00	39,24	778717,80	8829,00
Heifers not in calf	14	400	5762,4	50%	2881,20	41,94	120837,53	8388,00
Weaner								
September	91	240	21873,6	100%	21873,60	28,90	632147,04	6936,00
January	91	240	21873,6	100%	21873,60	Closed		0,00
Februrary	91	260	23696,4	100%	23696,40	32,85	778417,26	8540,90
April	182	240	43747,2	100%	43747,20	29,17	1276105,82	7000,80
August	91	240	21873,6	100%	21873,60	32,88	719203,97	7891,20

Year-round breeding sales

As previously mentioned, the sale of animals and the quantity are a function of the herd structure. The most notable distinction between the two structures, being the multiple sales of weaner calves over the production cycle. Typically, the sales of calves occur with 20% in September, 20% in January, 40% in April and 20% in August. However, due to the FMD outbreak which occurred during the production season it was not possible to sell calves at live sales which is the preferred method of sale during that time in January.

4.5.4 Market access options

Due to the FMD outbreak and the control methods imposed to contain and control the outbreak, market access was impacted. As the preferential method of marketing, the sale of weaner calves at live animal auctions was prohibited for a time and producers must make managerial decisions relating to the sale of their stock. Several options are available to the producer in this instance, all with their advantages and disadvantages. These include:

Private sales: instead of selling at live auctions a producer could potentially sell directly to a feed crawl operation if all legal obligations are met. Problems with this method could be, legal obligations regarding animal movement control and record keeping. The auctioneering process determines a fair price between buyers and sellers. This mechanism no longer functions when live animal auctions are banned. Requiring a sufficient number of animals to be marketable at one time, to allow for a private sale. These factors can result in higher transaction costs.

Slaughtering: For slaughtering to occur, feeding is necessary for an extended period of time. Feeding would require infrastructure to facilitate it, added capital expenditure to purchase feed, feeding is time consuming and you need to operate without that income until they can be slaughtered.

Waiting for live animal auctions to reopen, which was the assumption of the study: The main goal of closure of live animal auctions main goal was to limit the spread of FMD. The argument can thus be made that the worse and more widespread an outbreak occurs; the longer live animal auctions will be closed. From a producer’s perspective that represents time when they continue to incur expenses but no income from live sales. This can have an adverse impact on cash flow, the ability to settle financial responsibilities and reduced solvency.

Table 4.7: Breeding throughout the year sales quantity

Sales	Rate	Quantity
Bulls	20,00%	5
Cull cows	15,00%	90
Heifers not in calf	14,00%	15
Weaner	Total calves - replacement heifers	465
September	20,00%	93
January	20,00%	93
Februrary	20,00%	93
April	40,00%	186
August	20,00%	93

Table 4.7 illustrates the quantity of animals available for sale and for the sale of weaner calves at different times of the year for the control scenario. Most notable is that live animal sales were legally closed during the month of January 2020 and no sales could occur through the preferred market channel. Subsequently the sale thereof occured in February once live animal sales were legal again.

The significant difference between the system presented in Table 4.2 and Table 4.5 is that the latter indicates the sale value of weaner calves for several separate occasions when they were sold. The market for weaner calves is not fixed and several factors impacts on it, but most importantly in this case the sale price paid at different times throughout the year vary and so the price per animal received differs depending on when they are sold. Live animal auctions were closed in the month of January and so no price (R/kg) can be displayed.

4.5.5 Costs

Budget model construction makes use of standard accounting principles which applies specific cost-allocation principles within the model. A link between farm and financial management is created. Individual cost components of a whole-farm multi-period budget are discussed below.

Variable costs

Variable costs are costs which can be controlled in the short term. Costs which can vary within the framework of a specific production process as either the size of the enterprise changes or as the intensity of production per unit changes. No non-directly allocable variable costs are represented in the budget model. Only one farming division is represented in the model and so costs are either fixed costs or directly allocable.

Directly allocated costs

Variable costs can be readily allocated to an enterprise. The timing for the occurrence of variable costs during a production cycle has an important impact on cash flow and as an extension liquidity. Feed costs in livestock production are a key component of production and variable costs, due to it being an indispensable production input and a large cost component. Notable variable costs in livestock production which must be accounted for are: veterinary, dipping, inoculation, marketing, transport and the cost of purchasing replacement bulls.

Fixed Costs

Fixed costs are those incurred by the business regardless of production activities taking place or not. Typically, fixed costs are then not impacted by the scale or intensity of production. Fixed costs which are accounted for are such: bank charges, licenses, electricity, insurance, accounting fees, fuel and lubricant, cell phone/internet, farm watch security, maintenance, fencing and labour.

4.5.6 Cash-flow budget

A significant feature of the cash-flow budget is that expected cash income and cash expenditure are indicated at the time of receipt or payment. The statement reflects the source from which funds are generated during the period it is compiled over and also reflects the purpose for which funds were used during that period. The accounting period is divided into months so that the flow of funds can be shown and traced during the period for which it is compiled. The three main components of a cash-flow statement are income, expenditure and bank balance (Louw, Geyser and Jordaan, 2017).

- The quantity and timing of cash inflow and outflow.
- The effects on long-term profitability and financial viability.
- The planning of future capital needs and the extent and timing of repayment.
- Determining credit requirements and the repayment ability of the credit taker.
- Determining the timing and size of the surplus in order to exploit investment opportunities optimally.

The study of the cash inflow and outflow are paramount to the operation and success of a farm business. This is due to the fact that cash income received by the business can be seasonal, whereas payments occur throughout the year. The possibility exists that inputs are required, or unforeseen circumstances occur that require collateral at a time when livestock, or potentially crops, are not ready to be sold. Cash-flow budgeting is useful in the sense that it can indicate these unforeseen eventualities. It contributes to understanding the cyclical nature of income and expenditure in a farming system. Provision can then be made through credit to finance:

- Defer the payment of debt.
- Extend credit facility.
- Apply for additional debt in order to cover cash expenditure.

Individual months can either show an expected surplus or a shortfall. The closing balance can either be positive or negative. Interest is paid in the case of a negative balance and this is added to the calculation of the next closing balance. The closing balance from one month is equal to the opening balance of the next month.

4.6 Simulations

The whole-farm multi-period budget for a commercial beef cattle farm should represent the complexity and interrelated components therein. The model used for managerial and financial decision making should be able to simultaneously integrate the changes in managerial decisions such as herd structure or marketing. It should also be able to represent the financial implications as a result of changes. Timing of activities is another critical consideration which is incorporated into the system. The timing of expected income or expenditure has a major impact on a business's cash flow. In order to incorporate these requirements and complexities, the typical farm was modelled by mathematical equations and accounting in Microsoft Excel spreadsheets. In this way individual components can be linked through equations and thus capture the interrelatedness of the components.

In order to evaluate the expected profitability of FMD on each model and the production systems it represents, individual scenarios are simulated and the resulting changes to profitability calculated. Government policy with regards to FMD has the greatest impact on the overall industry. This is due to the closure of live animal auctions and the restriction of animal movement in order to prevent the disease from spreading. The exception is when a producer is directly impacted by FMD on his/her property, opposed to indirectly by policy, in which case direct control measure are implemented such as quarantine and slaughter of animals. The focus of this study is more on the effect of the closure of normal markets due to FMD rather than on the actual point of outbreak. Scenarios are based on a property which is indirectly impacted. No outbreak was recorded on that property or in any of the simulated producers' livestock.

The scenarios aim to incorporate the effect of the policy utilised during the actual outbreak, as well as a hypothetical event. In the hypothetical situation the outbreak occurs at a different time of year which coincides with weaning time for producers making use of a fixed breeding season. For a year-round breeding season, the hypothetical closure of auctions is when proportionally the most weaner calves are marketable. The duration for which live animal auctions are closed is the final consideration simulated. The duration of the closure has an impact on both the cash flow and the sales value of the animals. The ideal marketing weight is identified as 240kg and is reached at an age of roughly eight months. Due to the FMD control policy it is not possible to market these animals at that age and weight. The impact is multi-faceted, the more time passes where access to the market is restricted the older and heavier the animals become. Typically, and applied in this study, a reduced price per kg is incurred for weaner calves due to market demand for lighter, less expensive animals. In this study the assumption is made that weaner calves grow at a rate of 20kg per month, resulting in a five percent decrease in the average quoted R/kg price incurred for every 20kg more than 240kg. For example, if the average weight of weaner calves sold, the R/kg price utilised to calculate the value thereof, would be the average quoted price in that month discounted five percent.

The following simulations are conducted by applying the respective models:

The control scenario accurately represents the prices and policy which occurred during the production season being scrutinised, including closure of live animal auctions in December 2019 and January 2020. This is done for both production systems. The control scenario is then compared to two simulations for each of the two production systems.

Fixed breeding season

- Simulation 1: Closure of live animal auctions for the period of two months in April and May of 2020.
- Simulation 2: Closure of live animal auctions for the period of three months in April, May and June 2020.

Year-round breeding season

- Simulation 3: Closure of live animal auctions for the period of two months in April and May of 2020.
- Simulation 4: Closure of live animal auctions for the period of three months in April, May and June of 2020.

The simulations' conducted output is generated in terms of monthly net cash flow and the monthly closing balances. For reference, comparison can be made between the control and the corresponding simulations. Output is displayed both in table form and graphical representation in chapter 5.

4.7 Conclusion

The model development and theory pertaining to it is discussed in Chapter 4. Systems thinking approach is the theory behind modelling complex systems and a goal orientated method in order to achieve an outcome. Typical farm theory is discussed and adopted in this study in order to construct and evaluate the models and the respective simulations. The model constructions, segmentation and description are key to the development of the model and its structure in which key parameters are outlined. Market access options is a component which producers must consider in the event of an outbreak and the closure of live animal auctions, in the context of the study it additionally dictates the marketing choice and strategy which is utilised. Farm budgeting in terms of whole-farm multi-period budgets as well as monthly cash-flow budgets are the output of the integration of physical farm structure and financial modeling. The simulation component refers to hypothetical situations used to replicate FMD outbreaks at different times during the production cycle as well as greater magnitudes of outbreaks. The models constructed and simulations ran, enables the financial evaluation of results as is discussed in Chapter 5.

Chapter 5: Results and discussion

5.1 Introduction

In Chapter 4 the models and their various components were described. It elaborated on the characteristics of a typical commercial cattle farm as well as the typical herd structures. In this chapter the results of each model and the respective simulations conducted are presented in terms of the expected effect on profitability. For the simulation the assumption is made that an outbreak of FMD occurred within the production season. Results are discussed for both constructed models in each section. For the fixed breeding season and for the year-round breeding season model a FMD auction closure period is simulated. The costs incurred during one production cycle, both fixed and variables costs are shown and the value and timing of sales which generate revenue for each model is highlighted. Both income and expenditure, to show monthly cash flow for each enterprise, a visual representation of cash flow and structure of each model are shown. With the simulations constructed for both models in which hypothetical parameters such as the timing of the closure of live animal auctions and extension thereof are simulated and the expected effects on profitability is calculated.

5.2 Costs

The first consideration is costs incurred. Figure 5.1 and Figure 5.2 illustrate the monthly break down of fixed and variable costs for the production period starting in September and ending in August. This constitutes one production season, in which a FMD outbreak is recorded and the closure of the gathering and sale of live animals during December and January. This represents the previous closure which was December 2019 to January 2020. Costing was conducted for the control situation for both fixed breeding season as well as year round breeding season.

Variable costs for fixed breeding season

Variable costs are directly linked to production activities and a larger degree of monthly variation in expenditure is observed. Expenditure on inputs occurs when those inputs are required to be utilised in the production system. Feed costs and the purchase of replacement bulls are the two largest cost items, contributing 43% and 25% of variable costs for 2020 respectively. Marketing and transport costs are two expenses which are directly related to the sale of animals and so are expenses incurred at different times between the two production systems. Marketing represents 23% of total variable costs and transport cost, six percent. September, April and May are the three months in which variable costs spike the reason for each are as follows:

- September: The purchase of replacement bulls, done before the summer breeding season for the fixed breeding season system. This is to ensure there are sufficient bulls for breeding once calving takes place, maintaining an optimal bull to cow ratio. Additional production lick is purchased to supplement animals during the spring and summer.

- April: Winter supplement lick is purchased in April as it is the beginning of the winter months. In this month weaner calves reach marketable age and weight and so are sold. Transaction costs are associated with this activity. Transportation cost from the farm to the market are one component. A seven percent marketing cost is also paid to the livestock agent through whom the animals are sold which contributes to costs in this month.

- May: Feed is purchased in this month for the purpose of feeding cull cows to be slaughtered. Cull cows are slaughtered in August; however, the process of feeding these animals takes time in order for their body condition score to be of a high enough standard to be slaughtered by an abattoir. Concentrate and roughage are required to facilitate feeding. It is not produced on the property and so must be purchased.

Where the simulations are concerned for both fixed and year-round breeding seasons, the costs remain for the most part unchanged. However variable costs in the simulations that do change are those related to sales and marketing activity. For instance, marketing costs and transportation costs are incurred when animals are sold. In all the respective simulations, the date of sale of animals differs from that of the control and so the costs related to this activity occur at that time. No additional feeding costs were included during the period from when animals reach marketable weight, the closure of live animal auctions till their subsequent reopening.

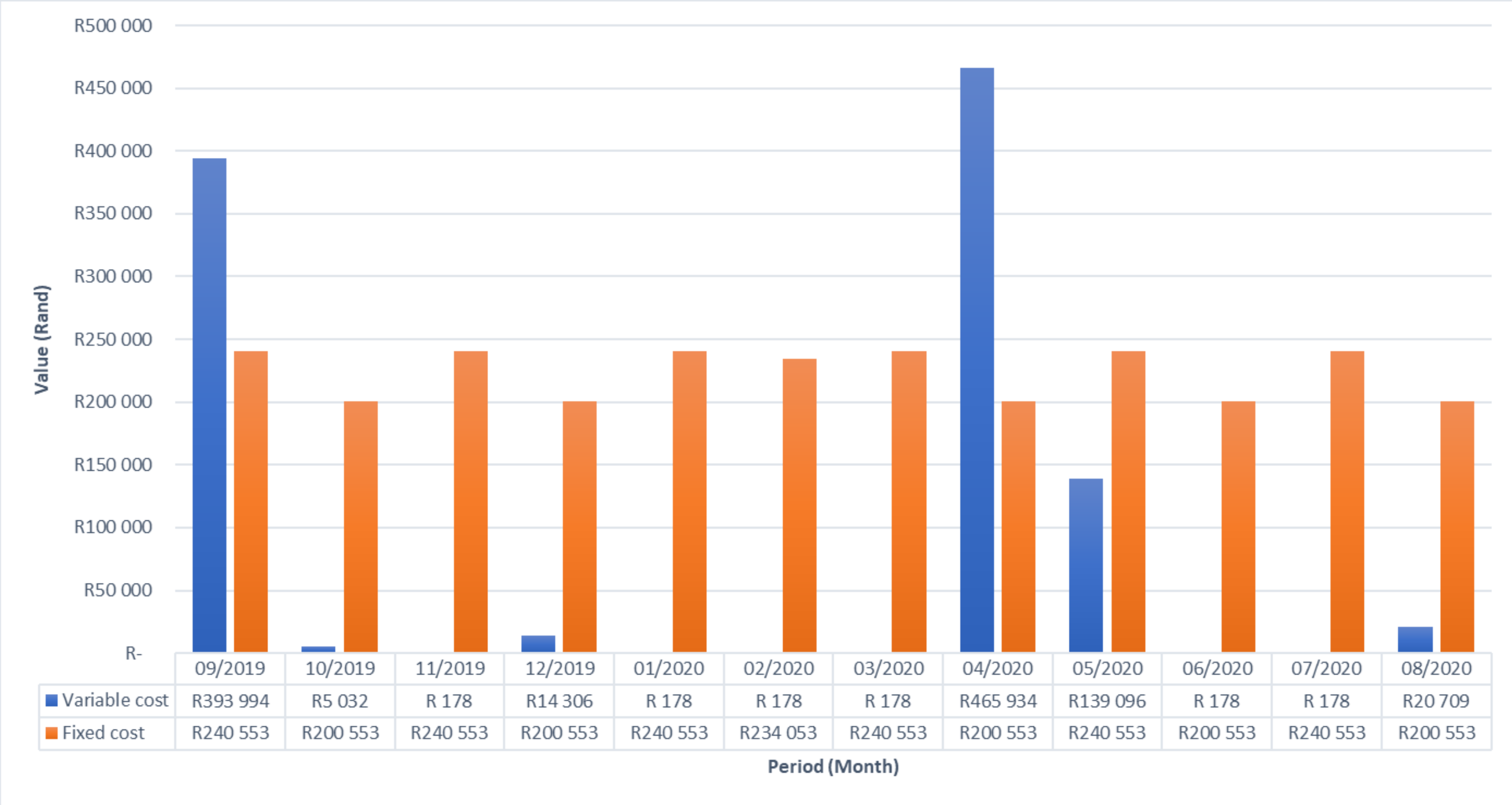

Figure 5.1: Fixed breeding season monthly fixed and variable costs between September 2019 and August 2020

Variable costs for Year-round breeding season

- September: The purchase of replacement bulls is conducted before the summer. Discussed in Section 3.7, in summer rainfall areas herds tend to calve naturally in the spring and so subsequent mating in the summer. Correct bull to cow ratio must be maintained for this period for optimal breeding and herd management. The sale of weaner calves is additionally conducted in September, the result thereof is transport as well as marketing costs.

- April: Winter supplement lick is purchased in April at the beginning of the winter months. Weaner calves are sold, incurring transport and marketing cost. Notably however monthly costs are lower as substantially fewer animals are sold as opposed to a fixed breeding season production system.

- May: Feed is purchased for the purpose of feeding cull cows for slaughter.

- September, January, April and August are all month in which weaners calves are sold and so as mentioned marketing and transport costs are incurred.

Notably, January is a month in which weaner calves are sold in this production system however as this was not possible due to the closure of live animal auctions, weaner calves were sold in February and so the attributable transport and marketing cost are incurred. As discussed in Section 5.4.3.

Figure 5.2: Year-round breeding monthly fixed and variable costs between September 2019 and August 2020

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Fixed costs

The fixed costs for both models, fixed breeding and year-round breeding, are identical in value and monthly distribution. Both models are based on the same typical farm and so the consistency in fixed cost expenditure is expected.

The fixed costs show little monthly deviation over the entire period. This is consistent with the principle that short-term changes in production output will not have an impact on fixed costs. The lowest monthly fixed expenditure is R200 533 and the highest R240 553. The deviation in monthly fixed expenditure can be attributed to costs such as licensing and accounting fees which is paid once annually. Fuel and lubrication are expenses incurred bi-monthly. As in Figure 5.3 fuel and lubricant accounts for nine percent of total fixed costs, resulting in monthly variation.

Labour, maintenance and loan repayment are the three largest costs in the enterprise, being 41%, 18% and 18% respectively. It contributes more than three quarters of the total fixed costs incurred. Labour is by a large margin the biggest expense incurred by the business, it includes owner remuneration, managerial cost and permanent staff costs.

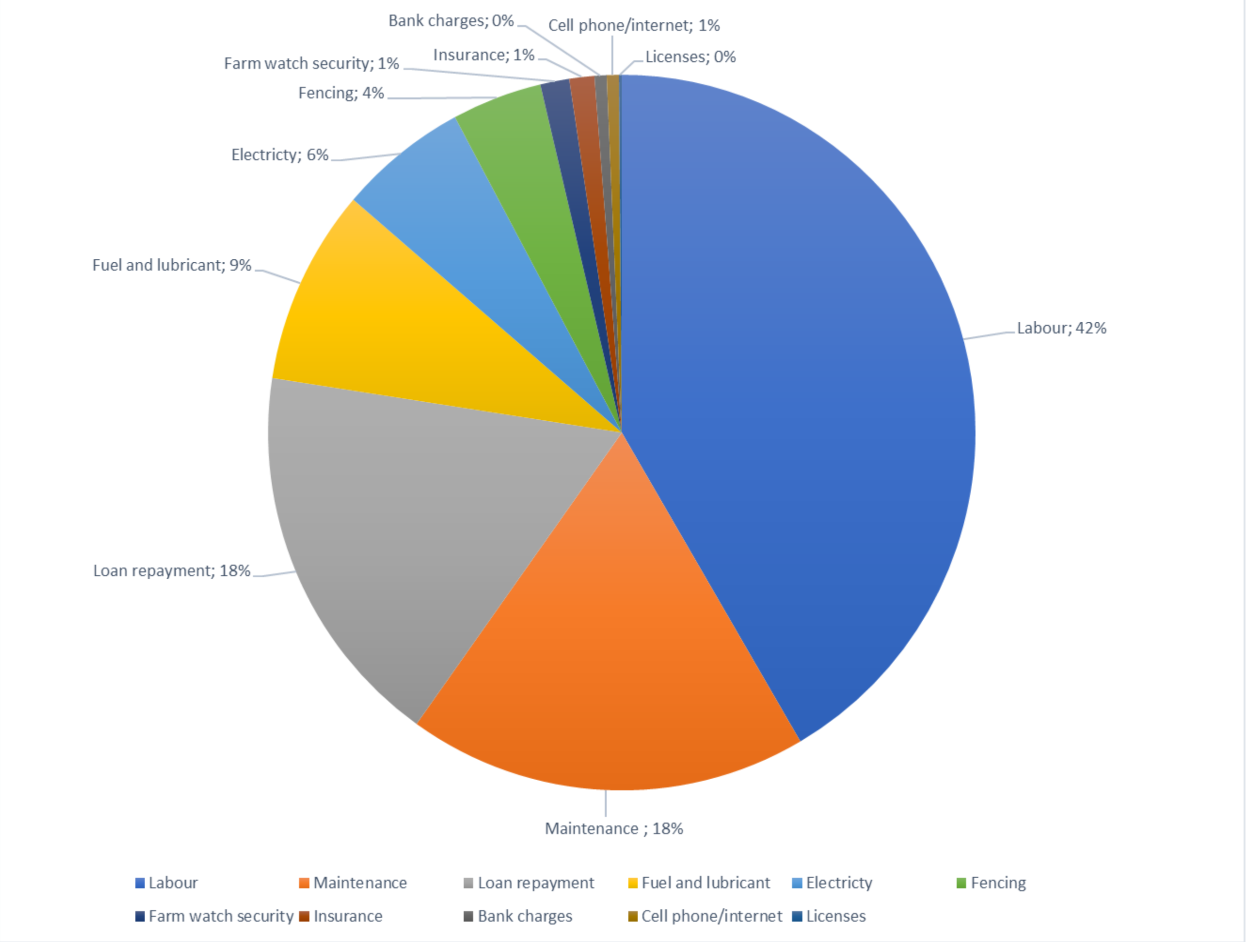

Figure 5.3: Proportion of each cost component of total fixed cost

5.3 Revenue

Several marketing channels are available to the producer for the sale of livestock; as previously discussed, live animal auctions are one and abattoirs another. Age, weight and body condition are factors which dictate the sale price for each animal. Further explanation can be found in Section 4.5.3. Bulls, cull cows and heifers not in calf, are sold to abattoirs for slaughtering. The value of the animal is calculated differently from that of live sales. The price per kilogram quoted is for the post slaughter dressed mass. Weaner calves are sold on the hoof and so the price quoted per kilogram is for the mass of the live animal (*Weekly Prices – RPO*, 2020).

Live animal auctions

Complex market forces of supply and demand determine the domestic prices for the beef industry. Factors such as production cycles, drought and outbreaks of animal disease are amongst the most important in terms of the supply and demand of cattle. Over the course of a production season supply and demand changes and so the price paid to producers varies accordingly. Table 5.3 and Table 5.5 illustrate the variance in price paid to producers over the production period, September 2019 till August 2020. Although a change in price cannot be completely attributed to one factor or event it can be said with certainty that it has an impact. The monthly average weaner calf price quoted fluctuated to a large degree throughout the year. A significant increase in price occurred between the time just prior to the closure of live animal auctions and after the reopening thereof. No monthly average price can be provided during the closure of live animal auctions due to there being no adequate price setting mechanism to determine the price. In a market where price is determined by supply and demand factors, a significant increase in price would suggest a shortage of animals once live auctions were reopened.

Abattoir sales

The slaughter of bulls, cull cows and heifers not in calf are equal for both production systems. Sales occurring at the same time and so matching prices are quoted. Tables 5.1 and 5.3 indicate in which months animals are slaughtered and the corresponding price per kilogram for each classification.

Abattoir sales account for 24% of revenue generated during the production cycle. Cull cows account for the largest share of 19% followed by heifers not in calf with three percent and bulls with two percent. Notably each category of animal slaughtered occurs in different months of the year, revenue generated therefore is distributed throughout the year. A total of R981 916 was generated through abattoir sales during the September to August production period.

Fixed breeding season

Revenue is generated on four occasions in the fixed production system, three sales to an abattoir and the sale of weaner calves. The fixed breeding season is structured in such a way that all calves reach marketable age and weight at roughly the same time. Therefore, one large sale of calves occurs once a year rather than multiple smaller sales throughout the year.

The sale of weaner calves in this system occurs in April, eight months from the start of calving, which occurs in September. This allows for calves to reach 240kg, the ideal marketing weight selected for the typical farm and production system. Factors such as breed, rainfall, environment and herd structure play a role in selecting the optimal marketing weight for a producer. Price per kilogram is on the hoof basis, in this production cycle and in the price received in April was R 29.17. For calves which weight 240kg, the value per animal is R7 000 as can be seen in Table 5.2. Once a two percent mortality is accounted for, 456 weaner calves are sold during this month resulting in an income of R3 190 264. Weaner calves thus comprise 76% of the total revenue received during one production cycle.

Table 5.1: Fixed breeding season sales date and price per kilogram (R/kg)

Prices (R)	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
A2/3	45,78	45,78	44,70	44,62	45,03	46,18	43,97	45,74	43,68	43,78	43,69	43,79
B2/3	39,01	39,16	40,15	39,91	41,63	41,94	43,83	41,42	39,71	39,73	40,62	40,52
C2/3	37,10	37,04	37,04	37,58	39,11	40,19	40,25	39,41	37,99	38,51	38,80	39,24
Weaner	28,90	29,22	26,27	Closed	Closed	33,52	32,84	29,17	29,85	29,97	32,04	32,88
	September	October	November	December	January	February	March	April	May	June	July	August

Table 5.2: Fixed breeding season sales value

Gross income from sales (A)	Quantity-mortality	Mass (kg)	Total mass (kg)	Dressing (%)	Dressed mass (kg)	Price (R/kg)	Total income (R)	Per animal (R)
Bulls	5	750	3528	58%	2046,24	40,25	82361,16	17508,75
Cull cows	88	450	39690	50%	19845,00	39,24	778717,80	8829,00
Heifers not in calf	14	400	5762,4	50%	2881,20	41,94	120837,53	8388,00
Weaner	456	240	109368	100%	109368,00	29,17	3190264,56	7000,80

Year-round breeding season

Revenue is generated at multiple times during the production cycle. There are three sales of stock to the abattoir and multiple sales of weaner calves to live auctions throughout the course of the production cycle. No fixed breeding season is in place, bulls are with the herd year-round and so cows' mate when they are ready. Thus, calves are born throughout the year. There is still a greater prevalence of births in the spring or summer in summer rainfall areas, as discussed in Section 3.7.

In this production season weaner calves are sold four times a year: 20% in September, 20% in January, 40% sold in April and 20% sold in August. This is done to replicate the staggered breeding and calving which occurs during the production cycle. The ideal marketing weight of weaner calves is 240kg the same as for the fixed breeding season. Table 5.3 and 5.4 show the price per kg and the value of each sale in the designated months.

In the control scenario there is no sale of weaner calves in January due to the FMD outbreak and thus the closure of live animal auctions. This had an impact on the planned sale of weaner calves as they were at the selected marketing weight of 240kg. As discussed in Section 4.5.4 three options are available to the producer in this instance. These are: private sales, slaughtering or waiting for live animal auctions to be reopened. In this instance and in the simulations, the final option, waiting for live animal auctions to open was selected. This option is in line with the goal of reducing the movement of live animals, preventing the spread of FMD and in line with the control strategy. Barriers to entry and transaction costs are two ramifications to consider in the two alternative options. When waiting for live animal auctions to reopen important considerations include feeding costs, time and the difficulty to determine a fair market price, not taking into consideration the price determining function of an auction.

With the closure of sales in December and then in January when weaner calves weigh 240kg, they are then retained on the property until the time when sales reopen, in this case in February. Naturally the animals gain weight during this time and so are heavier when they are sold opposed to when they 'were' to be sold. The market price quoted is for that of a 240kg weaner calf and so a deduction in price is made per increase in weight. Buyers of the weaner calves are less willing to pay for the heavier animals. The subjective nature of auctions, ramifications of closed sales and price determination were further discussed in Section 4.6. On average, every month that the animals are not sold 20kg are added to the live weight. A five percent decrease in price is applied for every 20kg over 240kg to the quoted monthly price.

Table 5.4 indicates that:

- 91 weaner calves were sold in September at a price of R28.90 /kg and a value per animal of R 6 936.
- 91 weaner calves were sold in February at a price of R 32.85 /kg and a value per animal of R 8 540.
- 182 weaner calves were sold in April at a price of R 27.18 /kg and a value per animal of R 7 000.
- 91 weaner calves were sold in August at a price of R 32.88 /kg and a value per animal of R7 891.

Once two percent mortality was accounted for 456 weaner calves were sold during the production cycle with the weighted average value per weaner calf was R 7 473. The income generated through the sale of weaner calves was R 3 405 874 which accounts for 77% of the total revenue generated through the sale of livestock.

Table 5.3: Year-round breeding season sales date and price per kilogram (R/kg)

Price (R)	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
A2/3	45,78	45,78	44,7	44,62	45,03	46,18	43,97	45,74	43,68	43,78	43,69	43,79
B2/3	39,01	39,16	40,15	39,91	41,63	41,94	43,83	41,42	39,71	39,73	40,62	40,52
C2/3	37,1	37,04	37,04	37,58	39,11	40,19	40,25	39,41	37,99	38,51	38,8	39,24
Weaner	28,90	29,22	26,27	Closed	Closed	33,52	32,84	29,17	29,85	29,97	32,04	32,88
	September	October	November	December	January	February	March	April	May	June	July	August

Table 5.4: Year-round breeding season sales value

Gross income from sales (A)	Quantity-mortality	Mass (kg)	Total mass (kg)	Dressing (%)	Dressed mass (kg)	Price (R/kg)	Total income (R)	Per animal (R)
Bulls	5	750	3528	58%	2046,24	40,25	82361,16	17508,75
Cull cows	88	450	39690	50%	19845,00	39,24	778717,80	8829,00
Heifers not in calf	14	400	5762,4	50%	2881,20	41,94	120837,53	8388,00
Weaner								
September	91	240	21873,6	100%	21873,60	28,90	632147,04	6936,00
January	91	240	21873,6	100%	21873,60	Closed		0,00
Februrary	91	260	23696,4	100%	23696,40	32,85	778417,26	8540,90
April	182	240	43747,2	100%	43747,20	29,17	1276105,82	7000,80
August	91	240	21873,6	100%	21873,60	32,88	719203,97	7891,20

5.4 Cash flow

In this section, the cash inflow and outflows of the models are illustrated and discussed. Figure 5.4 and 5.5 illustrate the monthly closing balance and revenue received in the farming business. Figure 5.4 refers to a fixed breeding season and Figure 5.5 to a year-round breeding season. Both range over two production periods, each production period starts in September and end is August of the following year.

Fixed breeding season

Data from Figure 5.4 indicates cash flow of a cyclical nature. Over both production seasons the same general trends occur, the amplitude thereof is impacted by revenue received and expenses incurred. The closing balance is characterised by extended periods of decreasing value and by a single substantial increase during each production season. Fixed and variable costs occur monthly and have a constant impact on the monthly closing balance. Cash income is seasonal whereas expenses occur year-round.

Revenue generated as previously discussed, occurs on four occasions during the production cycle, with the largest being in April and August, as discussed in Section 5.3. Weaner calves are sold on one occasion in this production system, in April accounting for 73% of the total revenue generated through the sale of livestock. In August revenue is generated through the slaughter of cull cows which results as an increase in the closing balance during those months. Extended periods without income and with incurred expenses constrain the cash flow and put the closing balance under pressure, potentially resulting in a negative balance. Table 5.5 shows that January, February and March are months with the lowest monthly closing balance. This is the furthest point in time from the last sale of weaner calves, before the next sale.

Substantial variation occurs between the maximum closing balance and the minimum closing balance. A high level of reliance is placed on the sale of weaner calves in April as it has the single greatest influence on the enterprise's finances.

Year-round breeding season

In contrast to the fixed breeding season, the year-round breeding season as portrayed in Figure 5.6 shows less variation in its expected closing balance. The difference between the maximum and the minimum closing balance is much smaller than in the fixed breeding season. Whilst cash flow variability does not necessarily have an impact on profitability it does mitigate risk, specifically risk from the closure of live animal auctions and the inability to market one's livestock.

Revenue is generated at multiples times during one production cycle, in addition to the stock being slaughtered the sale of weaner calves occurs on four separate occasions. Weaners are sold in September, January, April and August, with the largest proportion sold in April. In August revenue is generated through the slaughter of cull cows and the sale of weaner calves.

Due to FMD the second production cycle sales were different to that of the first production cycle. The sale of weaner calves was not possible in January 2020 due to the closure of live animal auctions for the control and spreading of FMD. The result was an unplanned extended period of time where revenue was not generated and expenses were incurred, having a negative impact on the closing balance. This is illustrated by the difference between the closing balance in January 2020 and January 2019. The subsequent reopening of live animal auctions allowed for the sale of the weaner calves and thus generating revenue in February.

Figure 5.4: Fixed breeding season monthly closing balance and monthly revenue for the period September 2018 till August 2020

Table 5.5: Fixed breeding season monthly net cash flow and closing balance

Control	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 634 547	-R 205 585	-R 240 731	-R 214 859	-R 240 731	-R 113 394	-R 158 370	R 2 523 778	-R 379 649	-R 200 731	-R 240 731	R 557 455
Closing balance	R 1 506 169	R 1 303 294	R 1 064 776	R 851 688	R 612 229	R 499 875	R 342 216	R 2 871 964	R 2 497 508	R 2 301 561	R 2 065 123	R 2 628 042

Figure 5.5: Year-round breeding season monthly closing balance and monthly revenue for the period September 2018 till August 2020

Table 5.6: Year-round breeding season monthly net cash flow and closing balance

Control	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 62 558	-R 205 585	-R 240 731	-R 214 859	-R 240 731	R 604 865	-R 158 370	R 754 470	-R 379 649	-R 200 731	-R 240 731	R 1 237 032
Closing balance	R 2 090 534	R 1 888 877	R 1 651 579	R 1 439 713	R 1 201 479	R 1 810 107	R 1 655 178	R 2 414 669	R 2 039 260	R 1 842 359	R 1 604 964	R 2 847 917

5.5 Simulations

Simulations constructed on the fixed breeding season, as well as year-round breeding season models, are focused on the closure of live animal auctions. The time of year in which the closure occurs as well as the duration of the closure are the two factors under scrutiny, with all other factors referring to the models remaining the same, *ceteris paribus*. Figures of the closing balance and revenue for all simulations can be found in Appendix 1.

Control: the control component of simulations is identical to that of Table 5.5 and 5.6 in which an accurate representation of the “normal” production cycle occurred. Of note is the closure of live animal auctions in December and January as previously discussed.

Fixed breeding season: Table 5.7
Simulation 1: Closure of live animal auctions for a two-month period in April and May.

The closure of live animal sales is simulated in this scenario to coincide with the time when weaner calves reach marketable age and weight. The closure of live sales during this time has a prominent impact on the cash flow of the enterprise. Discussed in Section 5.4 the fixed breeding season is characterised by extended periods without income from weaner sales which account for the majority of the revenue generated in a production cycle. The closure of live sales during the time in which weaner calves reach marketable age and weight, extends the time laps when income was generated, whilst expenses are incurred. The closing balance of Simulation 1 in Table 5.7 show that without the sale of weaner calves in April the closing balance for the month is negative and so additional financing is required to finance expenditure. A negative net cash flow of R401 318 is incurred in April and R379 649 in May. The closing balance is at its lowest in the month of May at negative R478 504. The sale of live animals is opened in June and so the sale of weaner calves occurs, and a positive net cash flow is recorded.

Simulation 2: Closure of live animal auctions for the period of three months in April, May and June.

As in Scenario 1, Scenario 2 simulates the closure of live animals sales coinciding with the time in which weaner calves reach marketable age and weight. The period for which live animal auctions are closed is extended for three months, April, May and June with the sale of live animals being resumed in July. The extended closure of live animal auctions for an extra month results in additional pressure placed on the closing balance. Fixed and variable costs are incurred whilst no additional revenue is generated, thus a negative net cash flow is incurred. The closing balance is the lowest in June at negative R 725 095. Additional external capital would be required to finance operations. The sale of live animals at auction is opened in July of 2020 which means the sale of weaner calves can take place and a positive net cash flow is recorded.

Year-round breeding season: Table 5.8

Simulation 3: Closure of live animal auctions for the period of two months in April and May.

With year-round breeding the sale of weaner calves occurs at multiple times throughout the year. The largest percentage of weaner calves is sold in April as previously discussed. In this simulation the closure of live animal auctions is made to coincide with this sale and the closure is for a period of two months, April and May. The result of the simulated closure is a negative net cash flow for the duration of the simulated auction closures. The closing balance is consequently under considerable pressure and decreases accordingly. Negative net cash flow of R 401 318 is incurred in April and R 379 649 in May. The closing balance subsequently decreases to its lowest value throughout the production period, indicating a constrained cash flow. Notably the closing balance remains positive at R 760 314.

Simulation 4: Closure of live animal auctions for the period of three months in April, May and June.

The extended closure of live animal auctions during the time in the production cycle where proportionally the largest quantity of weaner calves is sold is simulated. As in the previous simulation, negative net cash flow is experienced due to expenses incurred and the lack of revenue earned due to the lack of market access. The extension of the closure increases pressure placed on the closing balance. During the additional month of closed sales in June, a negative net cash flow of R 200 731 is experienced. The result is a decreased closing balance in June of R 558 503. In comparison with the control the closing balance experienced in this month is considerably lower. Notably a positive balance is maintained, and no additional financing is required. Subsequently the opening of live animal auctions is allowed in July and the sale of weaner calves occurs, resulting in a positive net cash flow and a closing balance that increases considerably.

Table 5.7: Fixed breeding season closing balance simulations: control, simulation 1 and simulation 2

Control	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 634 547	-R 205 585	-R 240 731	-R 214 859	-R 240 731	-R 113 394	-R 158 370	R 2 523 778	-R 379 649	-R 200 731	-R 240 731	R 557 455
Closing balance	R 1 506 169	R 1 303 294	R 1 064 776	R 851 688	R 612 229	R 499 875	R 342 216	R 2 871 964	R 2 497 508	R 2 301 561	R 2 065 123	R 2 628 042
Simulation 1	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 634 547	-R 205 585	-R 240 731	-R 214 859	-R 240 731	-R 113 394	-R 158 370	-R 401 318	-R 379 649	R 2 958 150	-R 240 731	R 557 455
Closing balance	R 1 471 590	R 1 268 643	R 1 030 053	R 816 892	R 577 361	R 464 933	R 307 202	-R 94 901	-R 478 504	R 2 484 812	R 2 248 756	R 2 812 057
Simulation 2	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 634 547	-R 205 585	-R 240 731	-R 214 859	-R 240 731	-R 113 394	-R 158 370	-R 401 318	-R 379 649	-R 200 731	R 3 179 958	R 557 455
Closing balance	R 1 432 866	R 1 229 838	R 991 167	R 777 925	R 538 313	R 425 804	R 267 991	-R 134 438	-R 518 371	-R 725 095	R 2 459 977	R 3 023 719

Table 5.8: Year-round breeding season closing balance simulation: control, simulation 3 and simulation 4

Control	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 62 558	-R 205 585	-R 240 731	-R 214 859	-R 240 731	R 604 865	-R 158 370	R 754 470	-R 379 649	-R 200 731	-R 240 731	R 1 237 032
Closing balance	R 2 090 534	R 1 888 877	R 1 651 579	R 1 439 713	R 1 201 479	R 1 810 107	R 1 655 178	R 2 414 669	R 2 039 260	R 1 842 359	R 1 604 964	R 2 847 917
Simulation 3	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 62 255	-R 205 585	-R 240 731	-R 214 859	R 355 621	-R 113 394	-R 158 370	-R 401 318	-R 379 649	R 1 056 217	-R 240 731	R 1 237 335
Closing balance	R 2 093 815	R 1 892 164	R 1 654 874	R 1 443 014	R 1 802 383	R 1 692 508	R 1 537 334	R 1 138 382	R 760 314	R 1 820 315	R 1 582 875	R 2 826 085
Simulation 4	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Net cash flow	-R 62 442	-R 205 585	-R 240 731	-R 214 859	R 355 435	-R 113 394	-R 158 370	-R 401 318	-R 379 649	-R 200 731	R 1 029 165	R 1 237 149
Closing balance	R 2 091 797	R 1 890 142	R 1 652 847	R 1 440 983	R 1 800 161	R 1 690 281	R 1 535 103	R 1 136 146	R 758 073	R 558 503	R 1 590 976	R 2 834 016

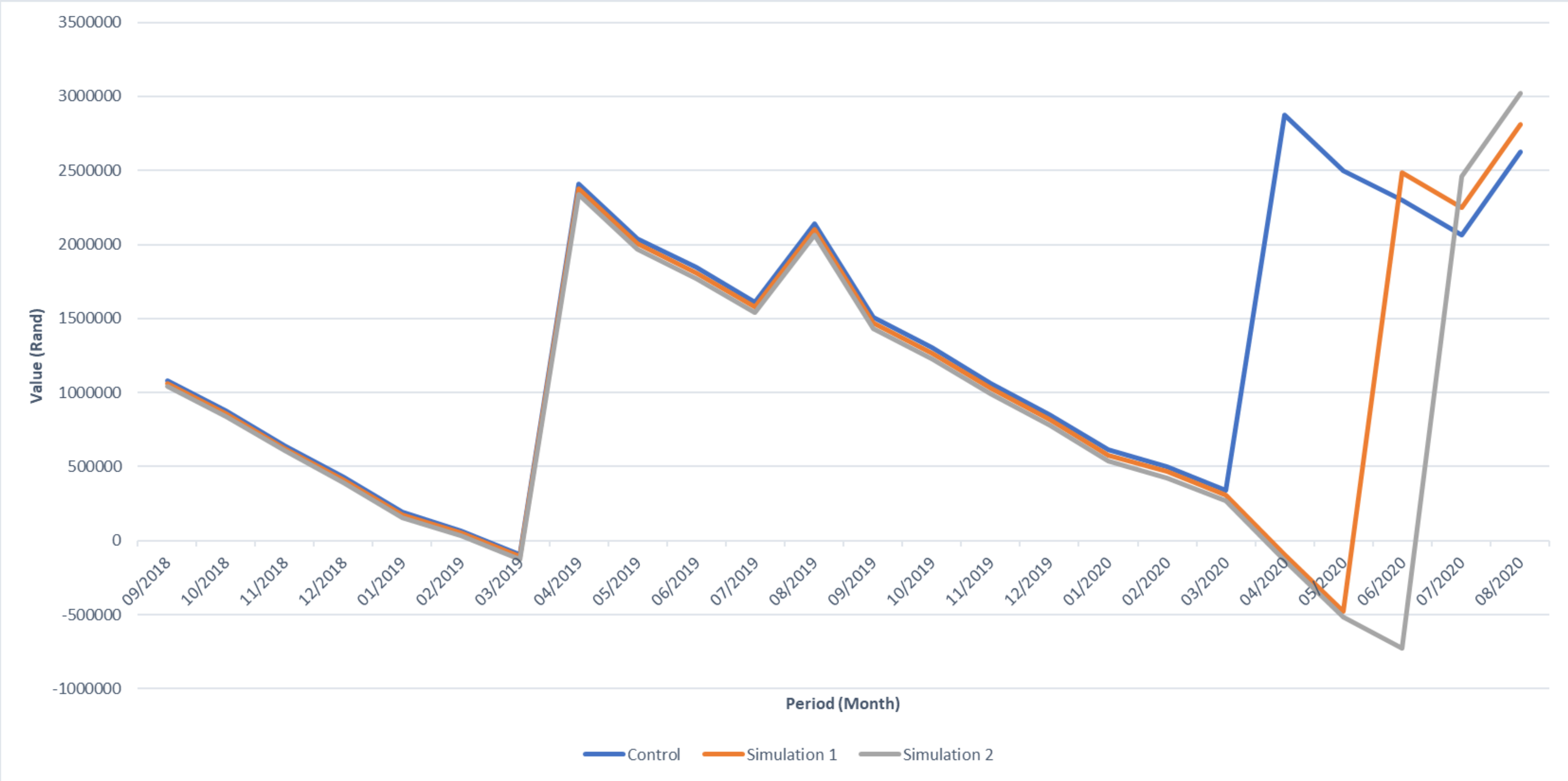

Figure 5.6: Fixed breeding season monthly closing balance for the period September 2018 till August 2020: control, simulation 1 and simulation 2

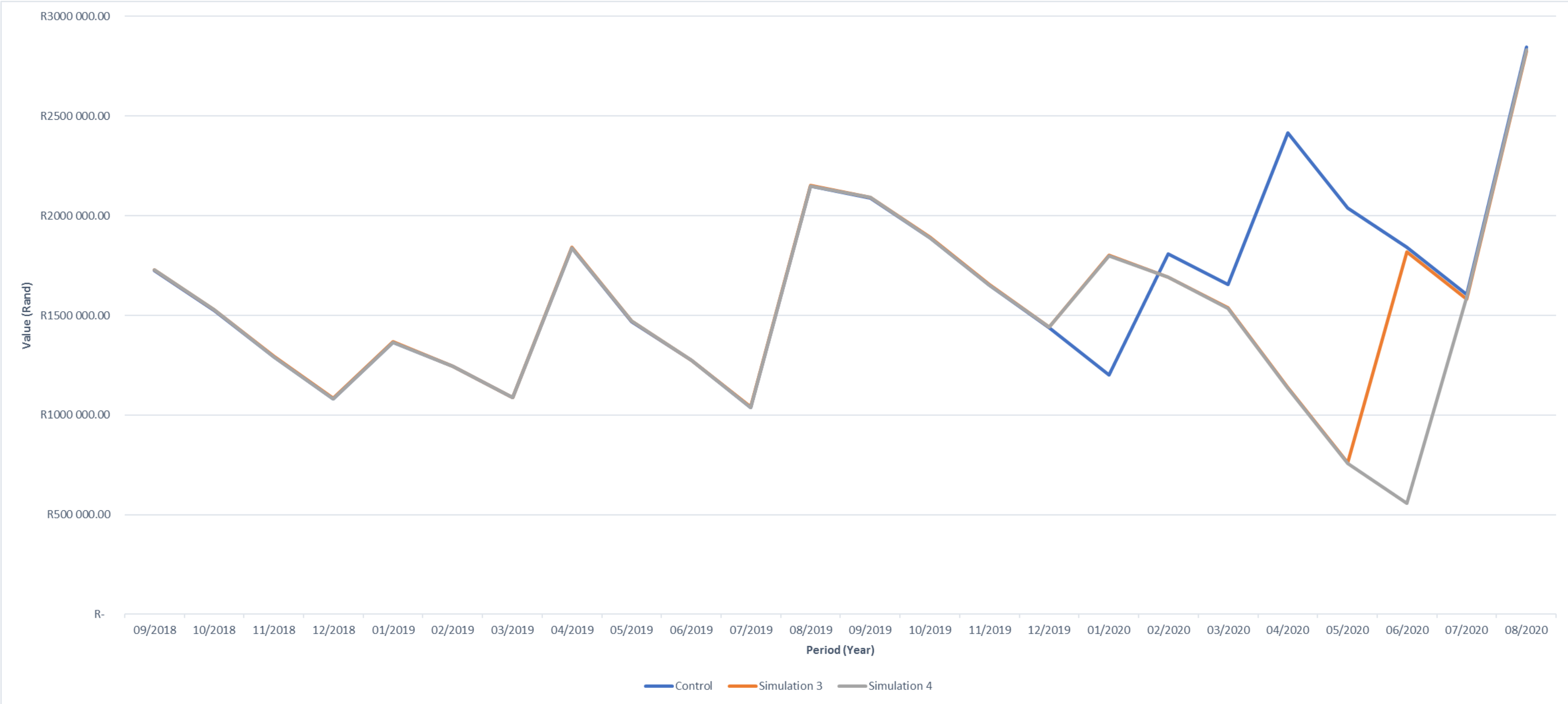

Figure 5.7: Year-round breeding season monthly closing balance for the period September 2019 till August 2020: Control, Simulation 3 and Simulation 4.

Chapter 6: Conclusion, summary and recommendations

6.1 Conclusion

In the coming years FMD is an animal disease which will continue to impact the South African cattle industry. This is due to it being endemic to Southern Africa and its prevalence in wildlife that transmits to cattle. Therefore, it must be taken into consideration by role-players at all levels, producers selecting a production system or government when implementing policies. Market access is a primary concern which is impacted throughout the industry. In the event of an outbreak, export opportunities to lucrative international markets are lost. Domestically market shocks occur in response to an outbreak, the resulting control policies implemented further impact the industry. The control policy implemented varies and so does the impact on industry. Factors such as the location of an outbreak, the extent and type of properties infected play a role in the control strategy implemented. Market access is the primary constraint felt by producers. The producers are then met with operational decisions within their business in order to manage and mitigate the impact of the disease, managing their revenue streams and expenses and thus maintaining satisfactory cash flow.

Regarded as one of the most important animal health diseases, FMD has little direct impact on the majority of producers. The indirect impact from an industry perspective is more important. Wider factors include control policy, market access, production and financial implications. This study aimed to evaluate the indirect impact of FMD control policies on producers, assessing specifically those who make use of a fixed breeding season and a year-round breeding season strategy. Hypothetical situations are applied to the constructed models in order to replicate potential variations of disease outbreaks at different times of year and increased magnitudes. The research conducted includes consulting relevant literature on FMD and the appropriate control strategies suggested. The models constructed were developed based on the concept of a typical farm theory for an extensive commercial beef cattle farm based in a semi-arid region of the North West province of South Africa.

In November 2019 an outbreak of FMD occurred and in response to the outbreak government implemented control policies on livestock in order to contain the disease. These control policies were implemented nationally and so the indirect impact of the disease was felt by producers nationally. Firstly, movement control of livestock was implemented and secondly a ban on the gathering of cloven-hooved animals was implemented and written into law in the national gazette. This included the live auction of cloven-hooved animals which includes cattle. The ban on the gathering of cloven-hooved animals was implemented on the 4th of December 2019 and lifted on the 18th of February 2020 whilst the outbreak was controlled and managed.

Importantly, although these control measures were implemented, alternative access to markets were available to producers. If regulations are met, as stipulated by the Minister of Agriculture, Land reform and Rural Development, the slaughter of animals may be permitted as the abattoir is the end point destination for those animals. Additionally, the on-farm sale of animals was permitted, provided that regulations were adhered to. Regulations which are applied include: no clinical signs of FMD on the property, the state veterinarian being notified and is in agreement to supervise the process, auditable records to be provided showing that all animals on the premises have been there for at least 28 days, no additional animals have been added during those 28 days. High transaction costs and the method for fair price determination are factors to be considered when making use of these marketing channels. For the purpose of this study the models represent a situation in which no sale of weaner calves occurs, be it at live auction or private on-farm sales until the reopening of live animal sales.

The purpose of this study was to evaluate the impact of FMD control policy on a typical extensive commercial cattle farm. Typically, this excludes stud breeders and focuses only on beef production. Different production systems that can be utilised by the typical farm are modelled through the use of whole-farm multi-period budgeting. The production systems modelled were for a fixed breeding season and a year-round breeding season. Both production systems are evaluated as their structure impacts the cash flow of the farm business and so the impact of FMD control differs. Systems approach and systems thinking was utilised in the modelling process due to the complexity and multi-faceted nature of farming systems. Systems approach allows for interconnection and the formation of relationships within budgeting models in complex systems. Budget models are in essence simulation models which are based on standard accounting principles. Due to this feature, structural production changes can be portrayed as financial output. The method utilised in this study was successful at representing the respective production systems, the control strategies implemented and the financial impact resulting thereof.

In the control situation and in the respective simulations when a fixed breeding season production system is utilised the results show a high variability in cash flow. Of the revenue generated, 76% is generated once during the production season when weaner calves are sold. Proportionally, less revenue is generated throughout the production season. The closing balance varies largely and is at its highest after the sale of weaner calves and lowest just before the sale of weaner calves. The results show that during the production season and the structure modelled on this farm, the outbreak occurred at a time where no weaner calves were ready to be marketed. Therefore, the closure of live auctions did not directly impact this fixed production system. However, this fixed production system wasn’t directly impacted it may well impact other producers using this system, making use of alternate breeding time windows. In Simulation 1 and 2, the closure of live auctions was modelled to coincide with the marketing of weaner calves in the production systems. This represents a "worst case" scenario for a producer and is realistic due to the possibility of an FMD outbreak occurring randomly. In a situation where an outbreak coincides with the time in the production cycle where weaner calves are ready to be marketed the monthly closing balance is directly impacted negatively. In the first month that live auctions are not allowed and so weaner calves can't be sold, the closing balance becomes negative, requiring external financing in order to cover the monthly expenses. The simulations show that in this scenario the longer the live auctions remain closed the more borrowed money is required to finance the business expenses.

When a year-round breeding season is utilised the results show a low variability in the maximum and minimum monthly closing balance. By using this production system weaner calves are marketed throughout the production season and so revenue is generated at multiple times. The results show that during the production season the outbreak of FMD did have an impact on the sale of weaner calves. The closure of live auctions during a time when weaner calves were ready for market meant that weaner calves had to be retained until the live auctions reopened. Expenses were incurred during this time with no revenue generated until the reopening of live auctions, yet the monthly closing balance remained positive during this time. For Simulation 3 and 4, the closure of live animal sales was replicated over a period where the largest number of weaner calves are sold, and the duration of the closure extended. The results show that, although the monthly closing balance decreased in both simulations, it maintained a positive monthly closing balance. Therefore, no external finance was required.

Both production systems can be impacted by FMD. The year-round breeding season is financially less severely impacted. When the outbreak of FMD occurs, it has a noticeable impact on the production system and the resulting finances. In this study it must be noted that not all management controls were considered and that the production systems are not exclusively designed to manage an outbreak of FMD.

The objectives of this study were achieved. Whole-farm multi-period budges were developed for a typical extensive commercial cattle farm. It was able to indicate the financial impact of the applied FMD control policies. The policy which is in question is the closure of live animal auctions for a period of time. A noticeable difference in the financial impact between the two production systems modeled was observed.

6.2 Summary

Quantitative, exploratory research was conducted in this study. It was done to financially evaluate FMD control policy’s impact on extensive commercial cattle farmers. Whole-farm multi-period budgets were constructed based on a typical farm. Two models were developed which made use of different production systems. One represented a fixed breeding season and the other a year-round breeding season. The financial evaluation was conducted by quantifying the monetary values in the respective budgets over multiple seasons as well as on a monthly basis. All relevant income and expenses were structured in accordance with the production system and the corresponding market prices. In Chapter 2 an overview and background of FMD was provided to present additional relevant knowledge about the disease and its practical and economic importance in order to better understand the disease and the relative factors needed to contain and control FMD. Topics such as pathogenesis, clinical symptoms and transmission are important. The transmission of the disease between wildlife reservoirs and livestock was elaborated on and highlights the importance of prevention as well as control policy due to its prevalence and endemic nature.

Chapter 3 includes the literature reviewed to contextualise both the cattle industry and the animal disease situation from a South African perspective. One needs to take note of the control measures and regulations which are placed on the industry.

In Chapter 4, the theory and structure of whole-farm, multi-period budgeting is described as well as the simulation component of modelling. Supporting theory such as systems thinking, strategic farm planning and the typical farm is described in the context of modelling. The structure and individual components of the models are described. This shows the mechanism used to model the differences in herd structure for the respective production systems illustrated. The simulation component is applied to the models and the individual simulations described for the respective production systems.

In Chapter 5, the results for the two production systems and the respective simulations were presented. Results from two production systems, one with a fixed breeding season and the other for a year-round breeding season, were shown. Two simulations were subsequently conducted on each system. The results show that all systems are affected by a FMD outbreak, the delay in generating revenue due to the closure of live animal auctions negatively impacts on the businesses cash flow. A fixed breeding season does carry the most risk if the outbreak is concurrent with the marketing season. The results were evaluated from a financial perspective and showed in this study that less variation in cash flow occurred in the year-round breeding season than in a fixed breeding season.

6.3 Recommendations

This study focused on quantitative, exploratory research in which the financial implications of FMD control policy were explored in different production systems. Although the method utilised in this study was appropriate, several limitations and constraints were experienced. One such constraint was placing a financial value on indirect costs. Whilst a negative externality may occur and have an impact on the business, the extent to which it has an impact and what that cost to the business translates to, is unclear. A national study on price volatility, directly caused by FMD could be useful.

Variation occurs nationally in terms of production as well as climate. Whilst the use of a typical farm was able to accurately represent the extensive commercial cattle farm in a semi-arid region of the North West province, it is not necessarily a fair representation of all producers nationally. A range of climates, biomes and production systems are present throughout the country and cannot be represented by a single typical farm / typology. Additionally alternate responses to the closure of live animal sales than that which was utilized in this study could be investigated. Scope exists for further research to be conducted in other regions of the country where conditions differ, and considerable production occurs. It may also be interesting to evaluate the effect of FMD in areas prone to other diseases such as red water.

FMD has an impact on all shareholders within the beef supply chain. In this study the focus was primarily on production level and the financial impacts which were experienced by producers. The financial, as well as structural impacts which are experienced by each link in the supply chain differ. For example, a feedlot which involves many animals from different locations being brought together will be affected differently by the control policies than that of a producer. Additionally, stud farmers' herd structure and marketing differ significantly from that of a commercial producer and so the impact of an FMD outbreak would be different. Each link in the supply chain impacts on one another, therefore, further investigation is required to better analyse these impacts enabling more informed decision for FMD control and policy.

Whilst this study was conducted on a financial level for commercial producers, scope exists in which the study can be up scaled in order for economic level analysis to be done. By doing such economic analysis the impacts of FMD could be seen from an industry level. The use of successive approximation models (SAM) are one way in which economic analysis could be conducted on the industry.

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Appendices

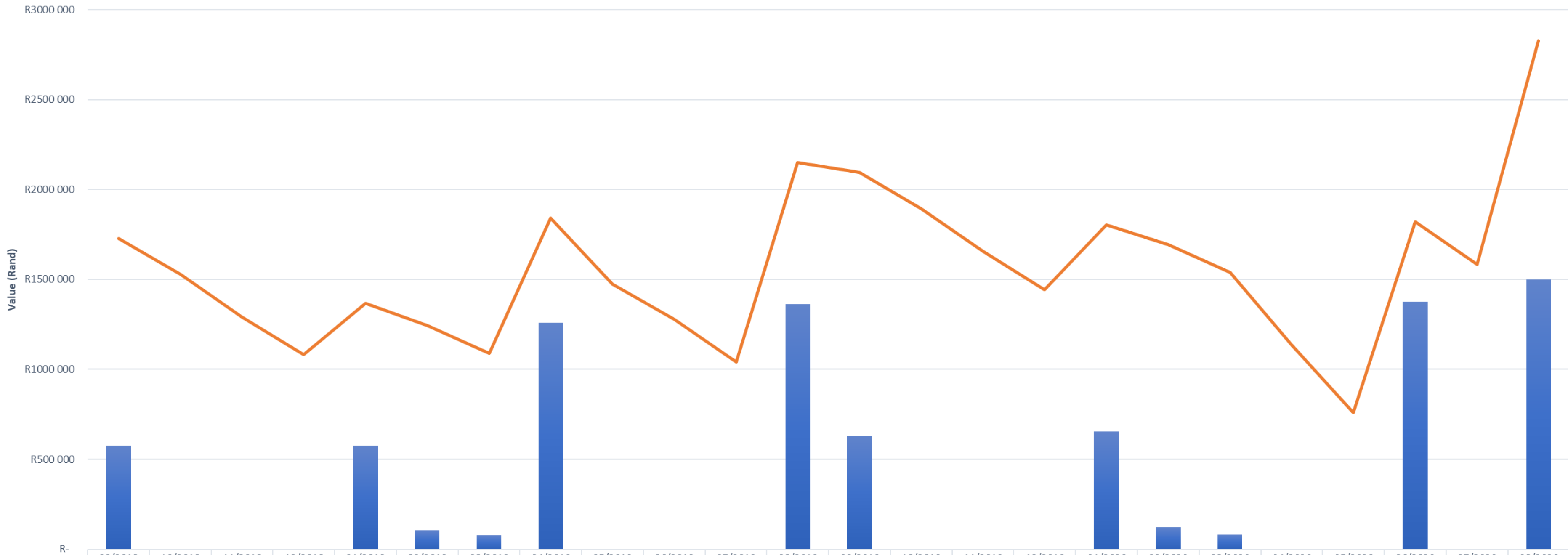
Appendix 1

Simulation 1: Fixed breeding season, live animal auctions closed during April and May 2020

	09/2018	10/2018	11/2018	12/2018	01/2019	02/2019	03/2019	04/2019	05/2019	06/2019	07/2019	08/2019	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Revenue	R-	R-	R-	R-	R-	R106 691	R78 494	R3145 42	R-	R-	R-	R739 623	R-	R-	R-	R-	R-	R120 838	R82 361	R-	R-	R-	R3723 16	R778 718
Closing balance	R1042 71	R841 188	R605 076	R393 621	R156 577	R32 270	-R127 660	R2336 08	R1968 05	R1773 17	R1539 00	R2064 43	R1432 86	R1229 83	R991 167	R777 925	R538 313	R425 804	R267 991	-R134 438	-R518 371	-R725 095	R2459 97	R3023 71

Period (Month)

Simulation 2: Fixed breeding season: live animal auctions closed during April, May and June 2020

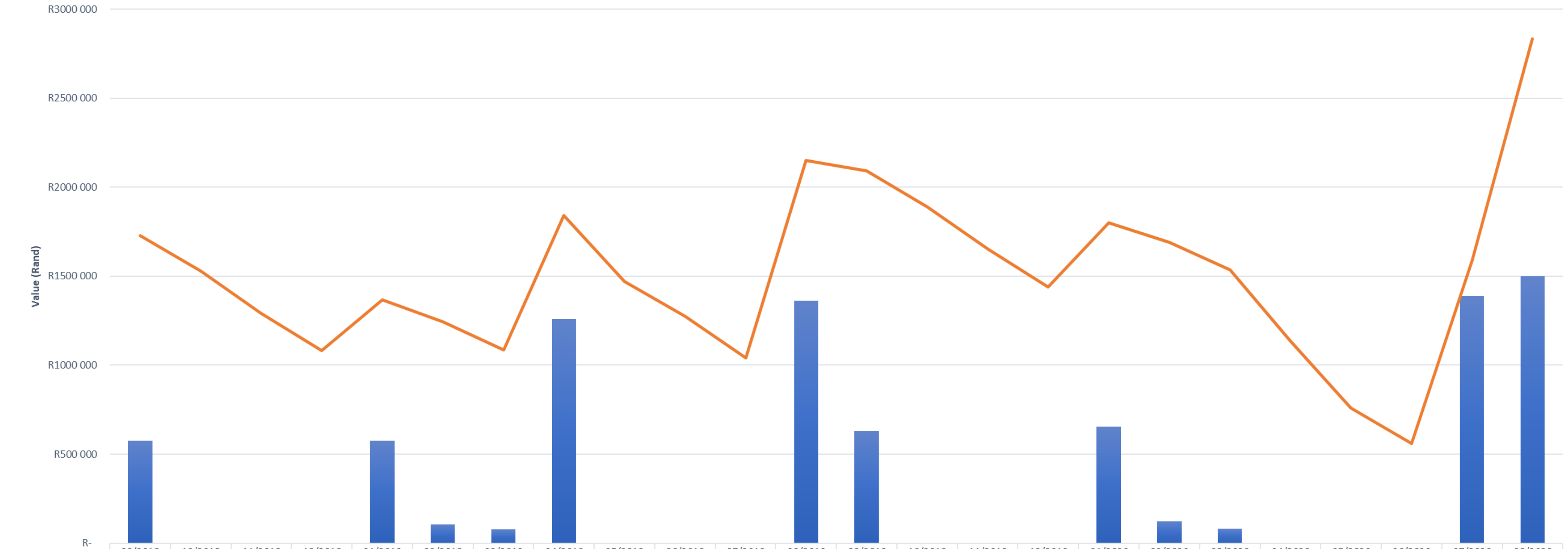


	09/2018	10/2018	11/2018	12/2018	01/2019	02/2019	03/2019	04/2019	05/2019	06/2019	07/2019	08/2019
Revenue	R576 151	R-	R-	R-	R576 151	R106 691	R78 494	R1258 169	R-	R-	R-	R1362 780
Closing balance	R1728 171	R1528 070	R1293 390	R1083 368	R1366 932	R1245 147	R1088 534	R1841 273	R1472 215	R1276 299	R1041 094	R2151 718

	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Revenue	R632 147	R-	R-	R-	R656 208	R120 838	R82 361	R-	R-	R1376 659	R-	R1497 922
Closing balance	R2093 815	R1892 164	R1654 874	R1443 014	R1802 383	R1692 508	R1537 334	R1138 382	R760 314	R1820 315	R1582 875	R2826 085

Period (Month)

Simulation 3: Year-round breeding season: live animal auctions closed during April and May 2020



	09/2018	10/2018	11/2018	12/2018	01/2019	02/2019	03/2019	04/2019	05/2019	06/2019	07/2019	08/2019
Revenue	R576 151	R-	R-	R-	R576 151	R106 691	R78 494	R1258 169	R-	R-	R-	R1362 780
Closing balance	R1727 099	R1526 996	R1292 313	R1082 290	R1365 670	R1243 882	R1087 267	R1839 641	R1470 579	R1274 659	R1039 451	R2149 890

	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020	04/2020	05/2020	06/2020	07/2020	08/2020
Revenue	R632 147	R-	R-	R-	R656 208	R120 838	R82 361	R-	R-	R-	R1389 980	R1497 922
Closing balance	R2091 797	R1890 142	R1652 847	R1440 983	R1800 161	R1690 281	R1535 103	R1136 146	R758 073	R558 503	R1590 976	R2834 016

Simulation 4: Year-round breeding season: line animal auctions closed during April, May and June 2020